

By 1952, the Electric Boat Company, builder of USS *Nautilus* in Groton, Connecticut, had installed the main turbine, condenser, reduction gear, and other parts in the submarine's engine room. The pressure vessel was installed in the reactor compartment. In June of that year, President Harry Truman presided at keel-laying ceremonies for the *Nautilus*, destined to be the world's first nuclear-powered sea vessel. Meanwhile, during the hot Idaho summer of 1952, Westinghouse engineers worked two shifts, then eventually three shifts around the clock. They installed systems and began leak tests. Reactor control equipment and coolant pumps came from Pittsburgh's Bettis Laboratory in the autumn. By November 1952, the reactor prototype was complete except for its nuclear fuel and two heat exchangers.¹²¹

By March 1953, the S1W Prototype achieved criticality, the world's first criticality of a pressurized water reactor. On June 25, 1953, the S1W achieved full design power and immediately embarked on a successful 96-hour sustained run, simulating a submerged crossing of the Atlantic Ocean. Two years later the S1W sustained a 66-day, continuous full-power run. This run was equivalent to a submarine travelling at high speed twice around the world -- without having to stop and refuel. The S1W Prototype created two other "firsts" for the young nuclear industry and the Navy. It was the first use of highly enriched uranium as a fuel and the first use of zirconium alloy as a construction material in nuclear reactors.

The S1W Prototype was the model for the nuclear core of the submarine USS *Nautilus*, the first nuclear-powered submarine in the world. The *Nautilus* proved its capabilities in 1958 when it became the first vessel to travel under the North Pole ice cap. The success of this 1958 sea trial reflected glory on the S1W Prototype. *Nautilus* commander, Bill Anderson, sent the following telegram to NRF workers from the White House upon his triumphant return to Washington, D.C.:

... during *Nautilus*' North Pole submerged transit from Pacific to Atlantic the performance of our engineering plant exceeded all expectations. To the first manufacturer of naval nuclear propulsion our sincere thanks for providing the plant that made possible this first transpolar crossing.¹²²

Cultural Resources Department.

¹²¹ Hewlett, *Atomic Shield*, p. 515; "Naval Reactors Facility, 1994."

¹²² The telegram is contained within the NRF "Historical

The S1W Prototype's early success was a prelude to the further development of naval reactor prototypes at the NRTS. A nuclear-powered aircraft carrier was in the design stage by 1952. The AEC and the Navy decided that Westinghouse would build the reactor and that the Newport News Shipbuilding and Drydock Company would develop the shipboard features. Westinghouse already had a good technical base for the project from its work on the reactor prototype in Idaho.

However, Rickover had to win over President Dwight D. Eisenhower and Congress, who were cutting budgets. The carrier was initially approved under President Truman in 1950, but was cut from the budget in 1953. The skyrocketing costs of nuclear ships (in all, the Nautilus program cost \$65 million) caused both the Department of Defense and Congress to question their cost-effectiveness. But the Korean conflict gave Rickover, by this time an admiral, the opportunity to defend his request for a nuclear carrier. He was victorious in 1954, when funds for the nuclear carrier were reinstated and the USS *Enterprise* resulted, the first nuclear-powered surface ship. Years later, Rickover referred to this experience in a 1968 speech to Congress, where he fought against withdrawing funds for the nuclear carriers USS *South Carolina* and USS *Virginia*. To support his arguments, he cited the *Enterprise's* many accomplishments in the Vietnam conflict.¹²³

New Prototypes, Personnel Training, and Spent Fuel: 1956-1969

On April 1, 1956, construction of the *Enterprise* prototype reactor began at the NRF. The ship itself was being erected in Newport News, Virginia. Two years later the Idaho reactor achieved criticality. Called the A1W (A for Aircraft Carrier, 1 for first model, and W for Westinghouse), the plant included two pressurized water reactors and associated steam equipment. Both reactors achieved full power in 1959. The NRF and the Bettis Laboratory used the A1W to test and develop different reactor materials. The information gained from A1W was used to design the C1W plant for the cruiser USS *Long Beach*, under construction in Quincy, Massachusetts. The A1W reactors continued in use after the carrier had been launched and were modified from May 1963 to November 1964 for a new surface-ship prototype. The A1W's new

Scrapbook" for 1958.

¹²³ United States Congress, *Hearing before the Joint Commission on Atomic Energy Congress of the US eighty-ninth congress 2nd session on Naval Nuclear Propulsion Program*, Jan. 26, 1966, p. 3. See also Duncan, Rickover, p. 162-163.

core reached criticality in April of 1965.¹²⁴

Having the submarine and aircraft carrier prototypes on the same site presented superb training opportunities. Rickover established an intensive nuclear training program in 1956 to support the growing inventory of nuclear-powered ships. Shipboard plant operators, specifically officers, first had to undergo six months of classroom instruction, then six months at a land prototype such as at the NRF. The prototypes gave the most realistic training possible because students learned their procedures and principles on operating reactors. If an officer passed this training, he was usually assigned to a nuclear ship and then undertook further study.

In a 1957 address to Congress, Rickover praised the Idaho training program: "The Arco Navy nuclear submarine training facility is most valuable... We have no better training facility in the Navy than we have there and it is absolutely essential for the future of nuclear power in the Navy that we train the people there...."¹²⁵ More than 12,500 Navy and civilian students received training at the S1W during its thirty-six years of operation. Approximately 14,500 were trained at A1W during its thirty-five-year life span.¹²⁶

The next prototype built at the NRF was the S5G (S for submarine, 5 for fifth model, and G for General Electric), a natural-circulation reactor. In the natural circulation mode, coolant water flowed through the reactor by thermal circulation. The natural-circulation reactor was a quieter and simpler system because large coolant pumps were no longer needed. "Silent" running was a distinct advantage in stealth operations. In 1956, Bettis Laboratory had completed preliminary studies for a small, natural-circulation reactor. After further testing had been completed, Rickover pressured the AEC to build a prototype at the Idaho site. Again, the new facility would match shipboard conditions, but with a new addition -- the prototype would simulate the motion of an operating ship at sea. His main concern was whether the natural circulation reactor could function

¹²⁴ Duncan, Rickover, p. 104-105; and "Naval Reactors Facility."

¹²⁵ United States Congress, *U.S. Congress, Joint Committee on Atomic Energy, Naval Reactor Program and Shippingport Reactor. 85th Congress, First Session, March 7 and April 12, 1957* (Washington, D.C.: USGPO, 1957), p. iii.

¹²⁶ Duncan, Rickover, p. 247-248; and "Naval Reactors Facility."

properly under those realistic circumstances.¹²⁷

Rickover went to Congress in 1957 to ask for funding. He used strong Cold-War rhetoric to make his point. Growing Soviet naval strength gave impetus to his words:

The efforts of the Naval Reactors Branch of the AEC...have given our Nation world leadership in the development of atomic power for naval propulsion....We believe that a fleet of nuclear powered underwater vessels capable of firing long-range missiles will ultimately decide the balance of world power and the maintenance of the peace.¹²⁸

After Congress and the AEC approved funding for the prototype, Westinghouse, which was in charge of Bettis Laboratory, moved several key personnel from Bettis to work on the space program. Furious about this, Rickover persuaded the AEC to take the natural-circulation project away from Westinghouse and give it to General Electric's Knolls Laboratory. Thus, General Electric arrived at the NRF as a contractor at the NRTS.

Construction of the natural circulation submarine prototype plant began in September, 1961. Four years later it achieved criticality. In June 1966, the S5G completed a simulated cruise of 4,256 nautical miles from New London, Connecticut, to London, England. In November, the natural circulation system performed well under normal seagoing circumstances. The next year the test was performed for AEC officials. They were pleased with the results. The Navy began building ships using the natural circulation system. Rickover immediately sent 114 men to train at the S5G.¹²⁹ The prototype continued operating for the next thirty years.

Handling the Navy's Spent Fuel--The Expended Core Facility, 1957-1969

When the SLW Prototype commenced power operations in 1953, it had its own hot cell, a heavily shielded enclosure for remote handling of radioactive material, and water pit for examining its own spent nuclear fuel. Using remote handling methods, workers first placed the spent fuel assemblies into the water pit and then cut them apart using a special hack saw. Selected

¹²⁷ Duncan, *Rickover*, p. 24.

¹²⁸ *Naval Reactor Program and Shippingport Reactor*, p. iii.

¹²⁹ Duncan, *Rickover*, p. 22-25; see also "Naval Reactors Facility."

subassemblies were moved into the hot cell for detailed examination and measurement. Of particular interest was the amount of distortion or other anomalies in the fuel as a result of its use. After this data had been gathered, the fuel components were loaded into casks for the short trip to the ICPP, where it was processed and its uranium recovered.

In 1957 a new set of hot cells and pools were built at the northwest perimeter of the NRF complex. Bettis Laboratory established design criteria for the Expended Core Facility (ECF). The engineer was Arthur G. McKee Company; and Paul Hardeman, Inc., the contractor. Its original dimensions were 340' x 190' with a 58' high bay down the center. The water pit, 34' x 50' under the high bay, dominated the center of the building. It was 30' deep at the fuel unloading area. Nine hot cells north of the water pit were connected to the pit by a transfer tunnel. Radiochemistry laboratories were north of the hot cells.

Railroad cars transported spent fuel from the other Navy facilities to the ECF. It arrived packaged in heavily shielded casks. The rail spur entered the high bay at the ECF's west end, into an area called the decontamination shop. The fuel was unloaded into the water pit, where it was separated from its structural material by a milling machine and core saw. From the pits, the fuel assemblies went to the hot cells for analysis.

Initially, the Navy sent about three fuel cores a year to the ECF; later, the shipments increased to five a year. The ECF also received irradiated materials from other NRTS facilities. Around 1960, MTR test specimens (plant materials, core structural materials, and naval reactor fuel) began going to the ECF for analysis. The specimens were first assembled at ECF, irradiated at the MTR (after 1970 at the ATR) at the Test Reactor Area, then sent back to the ECF for disassembly and examination. To handle these, the Navy built an additional hot cell and a water pit with a below-water-level observation room and a lead glass viewing window.

As the NRF developed additional prototypes, the workload at ECF grew. The number of ships in the Nuclear Navy also grew. With this growth, the ECF had to grow to keep pace -- eventually doubling in size from its original dimensions.¹³⁰

The buildings at the NRF are managed by DOE-Pittsburgh, not

¹³⁰ Information about the ECF came from Edgar L. Juell, "A Short History of the Expended Core Facility, (Idaho Falls: Naval Reactors Facility, 1990). See also "Naval Reactors Facility" and "Idaho Test Will Propel Huge Ship," *Idaho Falls Post-Register*, December 11, 1958.

DOE-Idaho. The scope of this report did not include a building inventory or assessment of historic significance. However, such an inventory and assessment was accomplished in 2000.¹³¹

It is clear that the NRF reactors, particularly the S1W Prototype, were of great significance in providing the United States with supremacy of the seas in the early decades of the Cold War. The three prototypes at the NRF are a major reason why the INEEL was of exceptional historical significance during the 1950s and 1960s. The primary mission of the NRF has been the research and development of nuclear propulsion plants. It should be noted that no new reactors were constructed at NRF after 1966, although new cores were inserted into the existing reactors.

SubTheme: Weapons and Military Applications
INEEL Area: Army Reactor Area (Auxiliary Reactor Area)

Origin of the Army Reactors Program: 1957-1965

The conventional method of supplying electricity to an isolated U.S. Army base or mobile field station was to transport a diesel generator to the site and operate a supply line to keep diesel fuel flowing from the nearest depot. Trucking or flying fuel to some bases, such as to Arctic locations where road access was impossible and flying was restricted, could be difficult, hazardous, and costly.

After World War II, the possibilities of atomic power tantalized the Army like it did the other military services. The allure was that a tiny handful of nuclear fuel might replace the logistical headache of fuel transport to remote locations. Or a nuclear power plant might be mobile, able to move with a field hospital or command center. Perhaps it could be portable, mounted on a barge and towable from one port to another as needed. Ideally, reactors could vary in capacity to serve a wide range of applications. They only needed to be small enough, light-weight enough, and cheap enough. The Army's nuclear power program aimed to meet these three challenges.

The Army organized an Office of Research and Development in 1951 to begin a nuclear research program. Its chief, General K.D.

¹³¹ Madeline Buckendorf, *A Historic Context of the Naval Reactors Facility: Including Historic Building Inventories and Assessments* (Idaho Falls: Prepared for the U.S. Department of Energy Pittsburgh Operations Office and Bechtel Bettis, Inc., by the Arrowrock Group, Inc., Boise, Idaho, November 2000).

Nichols, thought the Army's pursuit of small reactors might help to speed up the ultimate development of a commercial industry; he and others often used this argument as they sought support. The Army placed the Nuclear Development program under the supervision of the U.S. Army Corps of Engineers.¹³²

Meeting initial resistance from the AEC staff, which desired to retain the initiative in developing a commercial industry, the Army gradually acquired allies in Alvin Weinberg, director of Oak Ridge National Laboratory; Admiral Lewis Strauss, an AEC Commissioner after July 1953; and the Joint Chiefs of Staff, who declared an official military "requirement" for a nuclear power plant in December of 1953. The AEC and the Army organized its first project, which the AEC approved for funding in July 1954.¹³³

The Army's goal was to develop a family of three basic types of power plants. A stationary plant would be a permanent installation that could serve as a base in a remote area otherwise difficult to supply with fuel. It would not be designed for relocation elsewhere. A portable power plant would be pre-assembled for rapid erection in the field. A limited number of "packages" would make up the plant, each of which could fit in an air cargo transport or truck. The plant could be disassembled and then relocated to another site. A mobile power plant could move intact from one site to another without being broken down and reassembled at all -- possibly operate even while being moved.¹³⁴

Further refining its goals, the Army selected operating ranges for its nuclear plants. A "low power" reactor would produce in the range of 100 to 1,000 kilowatts. "Medium power" reactors would supply from 1,000 to 10,000 kilowatts, and "high power" facilities could range between 10 megawatts to about 40 megawatts.¹³⁵

The Army institutionalized these concepts in the names of its prototypes and experiments. Its first prototype, which went on line at Fort Belvoir, Virginia, thus carried the designation

¹³² Lawrence H. Suid, *The Army's Nuclear Power Program, The Evolution of a Support Agency* (New York: Glenwood Press, 1990), p. 3-8. This book is the most complete and useful source on the history of the Army nuclear program.

¹³³ Suid, p. 20-24.

¹³⁴ "The Army Reactor Program," *Nucleonics* (February 1959), p. 54; and John F. Hogerton, *The Atomic Energy Deskbook* (New York: Reinhold Publishing, 1963), p. 32.

¹³⁵ Hogerton, p. 32.

SM-1, a "Stationary Medium Power" reactor. Until it canceled its nuclear development program, the Army planned 17 different projects. Of these, seven went into service, seven others were designed, and three were experiments built at the NRTS in Idaho.¹³⁶

The Army Comes to the National Reactor Testing Station

The Fort Belvoir reactor, within eighteen miles of The White House, was a pressurized water reactor, the same type that Admiral Hyman Rickover had installed in the USS *Nautilus* prototype. Although other reactor concepts promised to embody virtues of light weight and simplicity so eagerly sought by the Army, pressurized water technology was the proven state of the art at the time. The Army dedicated the reactor in April 1957. To symbolize its potential for both peaceful and military uses, the first electricity generated by the reactor was used to run a printing press and a radar antenna.¹³⁷

Reactors cooled with pressurized water had several disadvantages, however. The coolant circulated in a primary loop through the reactor and exchanged heat with water in a secondary loop. The secondary loop transferred heat to a boiler, which produced steam to run a turbine/generator. The coolant piping, pumps, valves, controls, and instrumentation added considerable weight, bulk, and complexity to the total outfit.

The Army, therefore, set out to experiment with two alternatives. The first was a boiling water reactor. In this design, ordinary water boils as it passes through the hot reactor core. The steam generated here powers the turbine. The system eliminates the secondary loop and the heat exchanger equipment. The Army and AEC engaged Argonne National Laboratory to design a stationary reactor in the "low" power range that might be suitable for a remote location. It had the DEW Line (Defense Early Warning, later the Ballistic Missile Early Warning System) in mind, dozens of radar stations ringing the Arctic Circle on the watch for Soviet invasion. The Army wanted the plant small enough to haul on a 30-ton trailer. The prototype was named SL-1, and it was built on the NRTS at the Army Reactor Area (ARA).¹³⁸

¹³⁶ Hogerton, p. 33. Plants on the line were: SM-1 at Fort Belvoir; SM-1A at Fort Greeley, Alaska; PM-2A at Camp Century, Greenland; PM-1 at Sundance Air Force Base, Wyoming; PM-3A at McMurdo Sound, Antarctica; PL-3 at Byrd Station; and the *Sturgis*, a barge.

¹³⁷ Suid, p. 36-37.

¹³⁸ Suid, p. 82. For more technical detail on the SL-1 reactor,

The second alternative was a "gas-cooled" reactor, or GCRE. In this concept, a gas circulates in a closed loop through a water-moderated reactor to carry off the heat. The loop passes through a steam generator, which then runs the turbine. The system promised to be smaller and lighter than either of the other concepts. The Army hoped that ambient air might eventually be used as the coolant. The Army and AEC selected Aerojet-General Corporation to design it. As this would be the country's first gas-cooled reactor, testing had to determine its operating parameters and best fuel element design. Once that information was available, the plan was for Aerojet to build a prototype of a mobile low-power reactor -- the ML-1. Both of these alternatives and the ML-1 became clusters of activity at ARA.¹³⁹

Siting the Army Reactor Area

The SL-1 was ready to be built first. In August 1955, the AEC chose Pioneer Services and Engineering Company of Chicago as the architect/engineer. Bid requests began to go out in 1956, including one to build the circular steel tank that would house the reactor.¹⁴⁰ Construction began in 1957 and was finished in July 1958.

By this time, the NRTS no longer was a *tabula rasa* upon which a contractor could pick and choose a construction spot at will. Reactors and tests dotted the terrain, and each new experiment had to meet siting criteria administered by a Site Selection Committee at the NRTS and approved by the AEC in Washington. The Committee knew from the outset that the Army program would consist of three experiments. (The first name for the site was Army Reactor Experiment Area; the word "experiment" later was dropped.) The site was placed a few miles west of Argonne West and five miles east of the Central Facilities Area.

see "Army Reactor Program," *Nucleonics* (February 1969), p. 53-54 and insert.

¹³⁹ The GCRE was the eighth reactor type developed by the AEC Nuclear Reactor development program, selected for both military and civilian potential. US AEC press release, June 6, 1956; Papers of Senator Henry Dworshak, Idaho Historical Society, Mss 84, Box 55, File "AEC--Idaho Plant." Hereafter referred to as "Dworshak Papers."

¹⁴⁰ US AEC/Idaho Operations press release, December 11, 1956. Dworshak Papers, Box 55, File "AEC--Idaho Plant." The SL-1 was originally known as the Argonne Low Power Reactor, or ALPR.

The area was a master-planned four-cluster complex. The first cluster, ARA-I, was the administrative center. The three experiments were strung out along a connecting road and as close together as possible without compromising rules establishing minimum distances between reactors. The GCRE and SL-1 each required one mile; the ML-1, only a half a mile. (SL-1 was closer than one mile to the public highway, but it commenced before the one-mile rule was applied.) The four-cluster string was perpendicular to the direction of the most prevalent winds. This way, the risk of accidental releases from one reactor blowing over the other centers was reduced as much as possible.¹⁴¹

ARA-1 was the southern-most cluster of the four. It contained a hot cell building, a shop and maintenance building, guardhouse, pumphouse, hydraulic test power facility, and water and electrical utilities. Office trailers and a crew training building eventually were added. Its earliest buildings were constructed in 1959 and 1960.

SL-1, the first of the three projects, was next up the road at ARA-II. Completed in 1958, the site consisted of the cylindrical reactor building, a control room building with auxiliary equipment, and several small service buildings. The cylinder, made of quarter-inch thick steel plate, was part of the experiment. It was set on dummy piles to simulate construction methods used at DEW Line radar stations in permafrost. The reactor vessel, fuel storage well, and demineralizer for the water were in the lower part of the cylinder and shielded with gravel. Other equipment and shielding were in the upper two thirds of the building. The Army planned to use the SL-1 for training, so its operating contractor, Combustion Engineering, employed a military crew. Several earth berms were constructed at strategic places at the site. As at every other test area at the NRTS, a security fence and guard gate controlled entry.

The GCRE, at ARA-III was the next complex, ready for action in 1959. The reactor was in a rectangular building. Inside, the reactor operated within a sunken "swimming pool" filled with the moderating water. At the northern corner of the site stood a large tank for contaminated water, heavily bermed. The layout included a control and test building, a service building, a warehouse, gatehouse, petroleum storage, nitrogen storage tanks, and cooling tower along with fire protection, water, and sewer utilities. One of the buildings was a laboratory and fabrication

¹⁴¹ Norman Engineering Co., *Master Plan Study for the Army Reactor Experimental Area* (Idaho Falls: Norman Engineering Report No. IDO-24033, 1959), Section II (no page numbers). The master plan also provided for other facilities that the Army never did build.

center related to the development of the next project down the line at ARA-IV, the ML-1 prototype.

The ML-1 reactor was assembled in Downey, California, put on an Army semi-trailer, and hauled to Idaho, where it arrived in February 1961.¹⁴² The ML-I site (ARA-IV) was intended to simulate field conditions for training; therefore, it was relatively undeveloped. For example, water was trucked to the site from ARA-III.¹⁴³ The reactor control building was 500 feet away from the reactor, and only one or two other buildings were erected at the site. Most of the study work connected with ML-1 took place within GCRE buildings at ARA-III.

The Progress of the NRTS Experiments

SL-1 went critical for the first time on August 11, 1958, and produced electricity two months later on October 24. It was the first power plant reactor to use aluminum-clad fuel elements, which heretofore had been used only in test reactors like the MTR. It used a new alloy that overcame the low melting point of aluminum. After SL-1, aluminum alloys were used widely.

The GCRE, which went critical for the first time on February 23, 1960, tested two types of fuel elements, plate-type and then pin-type. The object was to find a fuel configuration that would have a long run before depletion. The pin-type promised to produce 300 to 500 kilowatts for a year without refueling. This design also reduced the shielding requirements for the reactor, which meant that the ML-1 prototype might meet the Army's goal of being transportable in four packages totaling no more than 38 tons.¹⁴⁴ The GCRE had frequent maintenance problems, and on April 6, 1961, the reactor was shut down for the last time because of a leak in some of its stainless steel piping. It was deactivated by July 1, 1962.

The Army then turned ARA-III to the support and testing of the ML-1 prototype reactor. The GCRE pool was converted to a dry pit with shielding on top to accommodate the ML-1. On September 21, 1962, ML-1 operated as a power plant for the first time in a short two-hour run, making history as the smallest nuclear power

¹⁴² AEC/Idaho Operations press release, February 11, 1961. Dworshak Papers, Box 122 B, File "AEC--Press Releases."

¹⁴³ IDO-24033, Section II.

¹⁴⁴ To James T. Ramey from Richard X. Donovan, November 21, 1960. Dworshak Papers, Box 112, File "AEC Idaho Plant." See also *Thumbnail Sketch*, April 1960, p. 17

plant on record to produce electricity. Also, it produced the highest core temperature of any previous reactor -- 1,225 degrees F. Furthermore, this was the first time a reactor was connected to a closed-cycle, gas-driven turbo-generator. It reached full-power operation on February 28, 1963.¹⁴⁵ During ML-1 tests, the operators trucked the reactor into a weather-sheltering metal building in the center of the ARA-IV area. The reactor control building was 500 feet away from the reactor just outside the perimeter fence. Evaluation, repair, and studies of the ML-1 took place within the GCRE buildings at ARA-III.¹⁴⁶

The ML-1 proved to be disappointing, typically operating only a few days or hours before shutting down because of leaks, failed welds, or other problems. Only four days after it reached full power, a leak shut it down. It was out of action until spring 1964. After that, operations continued, but still with breakdowns. Radioactive releases were typical of ML-1; the experimenters realized that if it were to operate in the field, it would place its operators in danger. ML-1 tests ended in 1965.¹⁴⁷

Meanwhile, in Washington, D.C., the Army Reactor Group had placed several prototype reactors on line in Greenland, Alaska, Wyoming, and Antarctica. Even though these had acquitted themselves well, the Group was having trouble persuading any of the services, including the Army, to order any of the plants. It appeared that the "life time" cost of a nuclear plant was lower than that of a conventional one, but the initial cost was far higher. When it came time actually to set a budget, the services opted for low first-cost alternatives. Economists suggested that this was false economy, but "balance the budget" pressures were more powerful.¹⁴⁸

The SL-1 Accident

On January 3, 1961, the SL-1 had been shut down for maintenance since December 23, 1960. Three military crew members on an evening shift were preparing the reactor for another run. A

¹⁴⁵ Suid, p. 91.

¹⁴⁶ See Photos from ARA HAER report: Nos. ID-33-D-96 through ID-33-D-102. These views show the ML-1 being moved from ARA-IV to ARA-III and set up for examination at in the GCRE pool.

¹⁴⁷ Suid, p. 92-93.

¹⁴⁸ "Economic Military Power Arrives, But Pentagon Hesitates," *Nucleonics* (April 1960), p. 27.

violent explosion occurred in the reactor vessel, killing all three men. This was the first -- and continues to be the only -- fatal accident in the history of American reactor operations.

The AEC immediately appointed an investigating committee to discover what had caused the accident. After interviewing hundreds of people, the committee never could say conclusively what had caused it. High levels of radioactivity in the building prohibited a detailed examination of its contents, although the technicians did manage to photograph parts of it remotely.

It seemed plausible that one of the crew had moved a control rod farther out of the reactor than was specified in the maintenance procedures. In four milliseconds, the reactor went critical, heated rapidly, and caused water in the core to flash to steam. The column of steam slammed into the lid of the pressure vessel, causing the entire vessel to jump from its foundation, shearing all of its piping connections and blowing shield plugs and shielding material from the top of the vessel. The men died from the impacts of the explosion rather than from the effects of nuclear radiation (although radiation in the reactor building was at lethal levels after the accident). Most of the radiation released from the reactor vessel by the explosion remained inside the building.¹⁴⁹

The investigating committee identified many problems with the management of the SL-1 reactor. One of the worst, and possibly a contributing cause of the accident, was that the fuel elements had been allowed to deteriorate "to such an extent that a prudent operator would not have allowed operation of the reactor to continue without a thorough analysis and review, and subsequent appropriate corrective action."¹⁵⁰

¹⁴⁹ Many sources describe and discuss the SL-1 accident, among them "SL-1 Explosion Kills 3; Cause and Significance Still Unclear," *Nucleonics* (February 1961), p. 17-23; a series of press releases in Dworshak Papers, Box 122B, File "AEC-Idaho Press Releases;" "Summary of the SL-1 Reactor Incident at the National Reactor Testing Station in Idaho on January 3, 1961," prepared by the Staff of the JCAE, January 10, 1961, also in Dworshak Papers, Box 122B, File "AEC-Idaho Press Releases;" "SL-1 Accident, Findings of the Board of Investigation," published verbatim in *Nuclear News* (July 1961), p. 13-16. A videotape *The SL-1 Accident* produced by the NRTS Idaho Operations Office shows film of the recovery effort and the disposition of the reactor building. See also William McKeown, *Idaho Falls, The Untold Story of America's First Nuclear Accident* (Toronto: ECW Press, 2003).

¹⁵⁰ "Findings of the Board of Investigation," *Nuclear News* (July 1961), p. 13.

The AEC hired General Electric to evaluate options for disposal of the reactor building. The reactor core, vessel, and fuel went to the TAN Hot Shop for analysis. The rest of the lower-level radioactive debris and contaminated soil was placed in a "burial ground" about 1,600 feet from its original location. Two pits and a trench dug to bedrock accepted the waste. Backfill over the debris provided shielding, and an exclusion fence surrounded the burial zone. This on-site burial was considered a better approach than transporting the material sixteen miles on a public highway to the RWMC and risking public exposure.

The AEC decided that the cost of continuing to fund tests of boiling water reactors like SL-1 would not produce worthwhile benefits. It phased out the program and shelved it for possible future use. The Army felt that the concept had progressed "quite well," but it also stopped funding the concept.¹⁵¹

After decontamination, the ARA-II buildings were converted for use as offices. The NRTS contractor set up a welding shop to provide training and qualification testing for welders and braziers.

The accident may have aroused doubts in the minds of some about the Army's nuclear power plant program, but if so, the effects were not immediate. Editorials from nuclear industry publications such as *Nucleonics* said that accidents should be considered inevitable, but that the industry should do everything it could to protect its outstanding safety record to date. The AEC soon prohibited reactors that were controllable with only one control rod. The accident aroused protests from the local Oil, Chemical, and Atomic Workers International Union, which urged Congress to enact legislation to improve safety of nuclear workers. The Union also protested the lack of an isolation ward at the NRTS dispensary, lack of shielded lead caskets for burials, and lack of instruments available to read radiation levels higher than 500 roentgens.¹⁵² Site managers agreed that it was ill-equipped to deal with high-radiation casualties, but also felt that their pre-planned emergency procedures had been carried out appropriately during the SL-1 accident.¹⁵³

¹⁵¹ Suid, p. 87.

¹⁵² To Senator Henry Dworshak from Donald E. Seifert and George Drazich for Local 2-652, May 11, 1961. Dworshak Papers, Box 122B, File "AEC--Idaho Plant."

¹⁵³ John R. Horan and C. Wayne Bills, "What Have We Learned? Health Physics at SL-1," *Nucleonics* (December 1961), p. 43-46.

Perhaps the long-term impact of the SL-1 accident is best measured by the frequency with which it was mentioned by anti-nuclear writers in the 1970s and 1980s. Books appeared containing lists of nuclear accidents, near-accidents, and mishaps, described in language aimed to outrage or frighten the reader. Sometimes the accounts of the SL-1 accident were quite inaccurate, but they helped alarm the public and inspire protests against nuclear power plants.¹⁵⁴

The End of the Army Reactor Program

In view of the continuing difficulty finding missions for their small reactors -- and the continuing difficulty in keeping the ML-1 from breaking down -- the Army and the AEC concluded that the ML-1 program might eventually achieve its objectives, but that it would cost too much. Nuclear plants, particularly in the low-power end of the spectrum, could not compete with diesel plants: Using the Army's Antarctica reactor as an example, the initial cost of the nuclear plant was \$6-7 million; for diesel, \$350,000. A nuclear plant required a crew of 20 highly trained men; a diesel plant, six.

Partly behind the Army's reluctance to continue financing nuclear experiments was the country's growing involvement in the Vietnam War. The Department of Defense needed funds to prosecute the war. First the AEC and then the Army phased out the funding for the ML-1 development program by June 1966.¹⁵⁵ This action effectively ended the involvement of the NRTS in the Army's nuclear development program.

An Army Ad Hoc Study Group took up the question of the rest of its program in 1969. One of the participants summed up the situation by saying, "Nuclear power is a solution in search of a problem." Basically, no military requirements existed for nuclear power. In the end, the group decided that it was only in selected remote situations that nuclear systems were cost-competitive with conventional diesel plants, that experiments should stop, but that study groups could continue.¹⁵⁶

¹⁵⁴ See for example, Harvey Wasserman and Norman Solomon, *Killing Our Own, The Disaster of America's Experience with Atomic Radiation* (New York: Delacorte Press, 1982); John Fuller, *We Almost Lost Detroit* (New York: Reader's Digest Press, 1975); John May, *The Greenpeace Book of the Nuclear Age* (New York: Pantheon Books, 1989); Leslie J. Freeman, *Nuclear Witnesses: Insiders Speak Out* (New York: W.W. Norton and Co., 1981).

¹⁵⁵ Suid, p. 93.

¹⁵⁶ Suid, p. 103-105. The quotation comes from an individual,

However, the Chief of Engineers, Lt. Gen. Frederick J. Clarke, could see little reason even to continue study groups. He permitted existing plants to operate until major problems forced them to shut down. In 1971, the Army Engineer Reactor Group lost its name and became the Engineer Power Group. Soon this group was examining excess generators returning from Vietnam. The Army experiment with nuclear reactors was over.¹⁵⁷

The ARA Complex at INEEL

All ARA buildings were dismantled in the 1990s except for the ML-1 Control Building at ARA-IV, which continues in use. As mitigation, the INEEL prepared a HAER report, HAER No. ID-33-D, which was approved and accepted by the National Park Service in 2001. The HAER report was required to document ARA-I, ARA-II, and ARA-III, but in the judgement of the author, the HAER would be more complete with documentation of ARA-IV as well. Thus, ARA-IV history, documentation, and photographs were included in the HAER report.

SubTheme: *Cold War Weapons and Military Applications*
INEEL Area: Advanced Reentry Vehicle Fuzing System Bunker

The Advanced Reentry Vehicle Fuzing System (ARVFS) facility was built at the NRTS for the U.S. Air Force to evaluate the impact of gamma radiation on certain packages of instruments related to the fuzing system of guided missile warheads. The facility consisted of a below-grade quonset hut covered with earth, a subsurface water tank open to the sky and built to shield spent fuel elements, and a support framework from which to suspend test packets over the gamma source. The bunker served as the control room during gamma exposures. The facility was on the east side of Lincoln Boulevard and northeast of the NRF.

During the mid-1960s, the American missile program was developing both offensive and defensive capabilities with respect to guided missiles. The ARVFS bunker and the gamma exposure of a fuzing system were a very small part of a major national priority to maintain weapons superiority over the Soviet Union.

After its initial use, the facility was used for a similar test in 1968 by health physicists at the NRTS to evaluate

unnamed by Suid, who prepared a briefing for the Ad Hoc Study Group.

¹⁵⁷ Suid, p. 108.

computer-generated codes (which predicted gamma radiation exposure in certain situations) against an actual exposure. The test exposed dosimeter film.

Other opportunistic uses of the facility occurred thereafter. In 1980, fuel rod pellets were subjected to various kinds of charges, including a shaped charge, in the water storage tank at the facility. In 1974 four containers of contaminated NaK, previously stored at EBR-I, were moved to the bunker for safekeeping and isolation.

The ARVFS bunker site was decontaminated and dismantled in 1997. As mitigation for this potentially historic property, the Department of Energy contracted for a Historic American Engineering Record report on the facility.¹⁵⁸

The ARVFS facility, which was of such short-term usefulness that neither electricity nor telephone were extended to the site, was a small part of the Arms Race. It represents one of a nearly infinite list of details executed to guarantee a weapon that would do the destructive work for which it had been designed.

SubTheme: Cold War Weapons and Military Applications
INEEL Area: Test Area North

Beginnings of the Aircraft Nuclear Propulsion Program: 1951

The idea for a nuclear-powered aircraft was envisioned before the end of World War II. Military advocates fought to have the idea given serious attention in the years after the war. The Aircraft Nuclear Propulsion (ANP) program -- as it would involve the NRTS -- began in 1951 when the Department of Defense decided that a nuclear-powered bomber was a military requirement. The concept for the weapon system was that a bomber would be able to remain aloft for at least five days, approach its target from any circuitous route, deliver the payload, evade enemy fire, and return home by any route desired.

When the AEC and the U.S. Air Force undertook the ANP program, they assigned the General Electric Company (GE) the task of developing a "direct cycle" heat exchange system for a turbojet aircraft. The NRTS opened up for GE a new site at the far northeastern end of the site -- Test Area North, or TAN. TAN

¹⁵⁸ Susan M. Stacy, *Idaho National Engineering Laboratory, HAER NO. ID-32-B, Advanced Reentry Vehicle Fuzing System* (Idaho Falls: INEL Report INEL-97-00066, 1997.) The summary of ARVFS activities in this section are drawn from this HAER.

is about twenty-seven miles from the CFA.¹⁵⁹

The Utah Construction Company broke ground for the first buildings at TAN in 1953. They were equipped and ready for serious experiments by Christmas of 1955. GE's objective was to set up a turbojet engine, connect it to a reactor, and prove that the heat from the reactor could propel the engine.

Major Facilities of the ANP Program

The project would require many support buildings in discrete activity areas. One of the first large buildings completed was the Assembly and Maintenance Building (A&M, or TAN-607). A sprawling one-story structure, it would be the place to construct, assemble, repair, and modify the experiment. The A&M contained a variety of fabrication shops and laboratories. The metallurgical lab contained X-ray machines for inspecting welds; the radioactive materials lab would examine spent fuel elements from the reactor and other radioactive samples. A Hot Shop, 52 feet wide by 160 feet long by 60 feet high, with its six-foot-thick shielded windows and master-slave manipulators, allowed for the remote handling of "industrial-scale work" and radioactive substances. A chemical lab handled other chemicals, and a photographic lab was available. "Cold" shops were equipped to repair jet engines, make and calibrate instrumentation, and assemble (prior to their initial test) the nuclear power plants that would be the subject of the experiments. This building was separated from administrative and other non-research functions by a 15-foot high earth embankment located atop a natural ridge formation.¹⁶⁰

The ANP support facilities were connected to each other by shielded roadways, tunnels, and a four-track railroad that would allow safe transport of people and heavy equipment from one area to another.¹⁶¹ GE built a unique shielded locomotive with the driver's cab surrounded by lead and water for the safety of the operator and passengers while transporting radioactively hot items.¹⁶²

¹⁵⁹ Stacy, *Proving the Principle*, p. 118-120.

¹⁶⁰ APEX-15, *ANPP Engineering Program Progress Report No. 15*, March 1955 (Cincinnati, Ohio: GE ANPP Department, Atomic Products Division), p. 10; see also *Thumbnail Sketch* March 1959, p. 13.

¹⁶¹ Susan M. Stacy, *Idaho National Engineering Laboratory, Test Area North, Hangar 629, HAER No. ID-32-A*, 1995, p. 22. Hereafter cited as "Stacy, Hangar HAER."

¹⁶² APEX-13, *ANPP Engineering Program Report No. 13*, September

The Initial Engine Test (IET) facilities were located north of the A&M Building. When it was ready for a test, the reactor/engine assembly was moved to the "test pad" from the assembly area. Mounted on a dolly, the assembly could be moved in any weather enclosed in a moveable all-aluminum building. Because of the weight of the reactor assembly, the railroad tracks consisted of four rails. Operators conducted the test from a shielded underground Control and Equipment Building (TAN-620). When an experiment had been concluded and the reactor shut down, the locomotive hauled the assembly back to the A&M building for post-test examination and further study.¹⁶³

The ANP Experiments

GE built three major "Heat Transfer Reactor Experiments" (HTRES). On December 30, 1955, HTRE-1 demonstrated that a nuclear reactor could be the exclusive source of power for an aircraft engine. This was the first time that heat from a nuclear power reaction operated a J-47 turbojet engine. The reactor generated heat, the heat was compressed and forced through the nozzle of the turbojet. In an aircraft, the nozzle exhaust would provide thrust. Measurements and additional tests continued through January 1957. The reactor/engine plant accumulated a total of 150.8 hours of operation.

In later experiments, engineers modified HTRE-1 so that they could test the impact of temperatures up to 2,800 degrees F. for sustained periods of time (and at even higher temperatures for shorter periods of time) on various materials within and near the reactor.¹⁶⁴

The first two experiments had been built without regard to the space or arrangement limitations that would be relevant in the body of an airplane. The third experiment, HTRE-3, was built with the components arranged as they would be in an aircraft. Full nuclear power was achieved in 1959 and for the first time, an experiment ran two engines at the same time on nuclear power. In the course of these experiments, ANP research advanced scientific understanding of ceramics, alloys, and other materials subject to high heat.¹⁶⁵

1954 (Cincinnati, Ohio: GE ANPP Department, Atomic Products Division), p. 10-11, 195.

¹⁶³ Thumbnail Sketch 1958, p. 14.

¹⁶⁴ Stacy, *Hangar HAER*, p. 46.

¹⁶⁵ Stacy, *Hangar HAER*, p. 46.

As the experiments progressed, GE built additional facilities at TAN. The Flight Engine Test facility was to house an anticipated airframe with typical crew compartments and aircraft control systems. The major structure was a hangar building (TAN-629) with a barrel-vaulted roof and open-span interior dimensions of 320 feet x 234 feet. Associated with the hangar was a shielded control building (TAN-630) and additional four-rail track leading into the hangar. The hangar was completed in 1959.¹⁶⁶

The project required additional test reactors to perform a variety of studies. The Shield Test Pool Facility (SUSIE), which included the SUSIE reactor, was used to examine the problems associated with shielding a human crew on an aircraft with an operating nuclear reactor aboard. Engineers tested prototypes or mock-ups of various shielding materials and configurations. The facility was located some distance from the other TAN facilities and was known as the "swimming pool" because it had two water-filled compartments into which reactors could be submerged for the tests. Near the pool was a platform and gantry crane for "in air" tests. A control building served both the pool and the platform. Construction began in 1958 and was completed in 1959.¹⁶⁷

Another support facility, the Low Power Test Facility (LPT), was located about one and one-fourth miles southeast of the A&M area and near the Shield Test Facility. Reactor assemblies were preliminarily tested here at "zero" or low power. Two low power reactors, the Hot Critical Experiment, and the Critical Experiment Tank were operated in the LPT in 1958, both associated with ANP research. Several buildings were constructed there including a single-story cinder block building (TAN-640) which contained two poured-concrete test cells. A wall five feet thick served as a shield between the cells and the rest of the facility. The walls between the cells were four feet thick, allowing personnel to work in one cell while the reactor was operating in the other.¹⁶⁸

¹⁶⁶ Pursuant to a Memorandum of Agreement with the Idaho SHPO, the TAN Hangar was the subject of a HAER in 1995. This document includes further design details of the Flight Engine Test Facility. See Susan M. Stacy, *Idaho National Engineering Laboratory, Test Area North, Hangar 629, HAER No. ID-32-A*.

¹⁶⁷ *Thumbnail Sketch* March 1959, p. 14.

¹⁶⁸ R.E. Wood et al, *Operating Manual for the Low Power Test Facility* (Idaho Falls: General Electric Report DC 59-8-718, 1959), p. 6.

Although GE demonstrated the principle of nuclear-powered flight, one of its major disappointments was to find that the reactor could not heat the engine air to the desired high temperatures, a requirement for fast bomber speeds. A nuclear airplane might be able to fly, but if it could not sprint at rapid speeds to evade the enemy or manoeuver quickly, it could not serve as a military weapon.¹⁶⁹

The End of the ANP Program: 1961

During the course of ANP experiments, the Department of Defense was simultaneously improving the technology of long-range guided missiles, another method of delivering a bomb to a far-away target. It proved to be more reliable and safer than a manned nuclear-powered bomber. In 1961 the new president, John F. Kennedy, was looking for funds to beef up the military's conventional forces and build the country's supply of Minuteman rockets and Polaris-firing submarines. He canceled the ANP program because, he said, "nearly fifteen years and about \$1 billion have been devoted to the attempted development of a nuclear-powered aircraft; but the possibility a militarily useful aircraft in the foreseeable future is still very remote..." The ANP cut would save \$35 million. Other military programs would, he felt, produce more tangible and immediate benefits.¹⁷⁰

Following the cancellation of the program in 1961, which came as a shock and a surprise to the unprepared GE employees, the mission of TAN facilities changed considerably. The hangar and its control building were never beneficially used for an airplane, for example. But the hot shops, laboratories, fabrication and assembly shops could be turned to other demands and other programs. Many ANP facilities were altered and reused for purposes other than their original ones. Others remained vacant or underused for years. In 1970 a private industrial council based in Idaho Falls, interested in marketing the vacant spaces at NRTS, estimated that 20 vacant buildings with over 223,000 square feet of floor space were available -- most of them at TAN.¹⁷¹

¹⁶⁹ Stacy, *Hangar HAER*, p. 46.

¹⁷⁰ "Kennedy Asks \$2 Billion Defense Insurance Hike," and "A-Plane Work Halt Asked by JFK in Defense Message," *Idaho Daily Statesman*, March 29, 1961, p. 1 and p. 6 respectively.

¹⁷¹ Dr. E. Fast, compiler, *Potentially Available Facilities at the National Reactor Testing Station* (Idaho Falls: Eastern Idaho Nuclear Industrial Council, February 1970), p. 14.

False Starts and New Programs at TAN in the 1960s

Another nuclear-technology program that had been underway in the United States during the 1950s was a program called Systems for Nuclear Auxiliary Power (SNAP). The object of this research was to devise a compact auxiliary power system for space vehicles and satellites. By the 1960s SNAP was a joint project of the AEC and the National Aeronautics and Space Administration (NASA).

Related to the SNAP program, the AEC prepared to conduct experiments with a Lithium Cooled Reactor (LCRE). The AEC envisioned a nuclear reactor that could power an electrical generator. It would have to be small and light-weight, but able to generate high power levels. The AEC contracted Pratt and Whitney (P&W) in 1962 to modify the TAN hangar building for the lithium-cooled-reactor concept. P&W already had done preliminary development of the concept.

P&W started on the modifications. The hangar building would house the experiment, while the hangar's control building, parts of the A&M building, the Health and Safety Building (TAN-607), and other buildings would house ancillary features of the project. But the work had barely begun before the AEC and NASA redirected the SNAP program, and the remodeling stopped abruptly.¹⁷²

After the SL-1 reactor accident in January 1961, many TAN shops and laboratories were used in the analysis and clean-up that followed the accident. The AEC gave GE the contract to decontaminate and dispose of the debris, and GE used its many hot shops and laboratories for this work, glad to supply employment to at least a few of its ANP personnel.¹⁷³

With its truncated staff, GE also took overflow work from some of the other contractors at the NRTS and did hot cell work for them. SUSIE was particularly popular. Now that the unique "swimming pool" was available to the rest of NRTS, it was in demand 24 hours a day all week long.¹⁷⁴

GE operated the Fast Spectrum Refractory Metals Reactor, a low-power critical facility, in the LPT from March 1962 to 1968.

¹⁷² Stacy, *Hangar HAER*, p. 57.

¹⁷³ Stacy, *Hangar HAER*, p. 56.

¹⁷⁴ To Henry Dworshak from John W. Morfitt, GE Idaho Test Station, September 26, 1961; Dworshak Papers, Box 122 B, File: AEC Idaho Plant.

The main work of this reactor was to collect data for a proposed reactor concept called the 710 Reactor. This was another concept for developing a compact, high-temperature reactor for generating power in space. The reactor was to use tungsten and tantalum. The project was discontinued in 1969 when it was determined that existing non-nuclear technology could provide power needs in space.¹⁷⁵

Also at the LPT, GE operated the 630-A Reactor Critical Experiment to explore the feasibility of an air-cooled, water-moderated system for nuclear-powered merchant ships. Further development was discontinued in December 1964 when decisions were made to lower the priority of the entire nuclear-powered merchant ship program.

Other experiments at TAN in the late 1960s were the Cavity Reactor Critical Experiment (CRCE) and Thermal Reactor Idaho Test Station (THRITS). Both of these were operated for the AEC by the Idaho Nuclear Corporation. The CRCE was installed in one cell of the LPT facility. It was a nuclear mock-up of a reactor having complete spatial separation of its low-fuel-density core and surrounding moderator -- a concept proposed by the NASA Lewis Research Laboratory for more efficient rocket propulsion. The THRITS experiment was housed in the second cell of the LPT and served as a thermal neutron source for several short-term tests.¹⁷⁶

In May 1963 modifications were made to the Shield Test Pool Facility to house the Experimental Beryllium Oxide Reactor (EBOR). The project's objective was to develop the technology for using beryllium oxide as a neutron moderator in high-temperature, gas-cooled reactors. TAN-645 was built as the control and administration center, and TAN-646 was for the reactor building. While EBOR was under construction, progress was made elsewhere on developing graphite as a moderator, reducing the importance of developing an alternate moderator.

Following a now-familiar pattern, the AEC terminated the EBOR program in 1966 soon after it redirected its policy toward a much narrower scope of reactor research. Only those reactor concepts that held promise for economical (commercial) power production and were efficient users of nuclear materials were of interest to the AEC. (See discussion above relating to Argonne West and the breeder reactor.)¹⁷⁷

¹⁷⁵ *Thumbnail Sketch* 1969, p. 38.

¹⁷⁶ For an illustration of the gas-core reactor concept, see p. 127 of Stacy, *Proving the Principle*.

¹⁷⁷ *Thumbnail Sketch* 1969, p. 37-38.

The ANP program represented the expenditure of about \$1 billion across a period of fifteen years, a huge commitment of the national treasure in pursuit of weapons supremacy over the Soviet Union during the Cold War. The buildings and experiments at TAN represent a remarkable legacy of the Cold War, both nationally and in Idaho history. Although not all of the money was spent in Idaho, this was the place where engineers proved that nuclear-powered flight could be achieved. Some of the buildings and facilities were one-of-a-kind creations: the hangar building, the "swimming pool" reactor, the industrial sized hot shop.

Within the last decade, a number of TAN buildings have been decommissioned and dismantled. The Initial Engine Test Facility, with its test pad, exhaust stack, railroad turntable, guard house, utility support buildings, and control bunker have been demolished. An 1956 Administration Building was dismantled, and one of the maintenance and assembly buildings (TAN-615) has been demolished. Many other buildings are in "shutdown" status awaiting further mission or other disposition.

With the end of the Air Force program in 1961, the TAN buildings lost most of their functions with respect to the "Cold War and Military Applications," one of the four themes describing reactor research at the INEEL in the 1950s and 1960s. A few NASA-related programs came and went, but much of the work at TAN shifted to another theme entirely, that of supporting the growing commercial nuclear power industry by doing research that would improve "Commercial Reactor Safety."

SubTheme: Commercial Reactor Safety
INEEL Area: The SPERT/PBF Area

The AEC Reactor Safety Program: 1955-1962

With the Atomic Energy Act of 1954, Congress and the AEC aimed to encourage the development of a commercial nuclear power industry. Of great concern was the safe operation of future nuclear power plants. Clearly, reactors would be located near their markets in heavily populated areas.

In 1953 the AEC's Advisory Committee on Reactor Safeguards (ACRS) had formed from a merger of two safety groups: the Reactor Hazards Committee with members appointed by the AEC, and the Industrial Committee on Reactor Location Problems, whose members came from private industry. These groups concerned themselves with the location of reactors, their operational safety,

radioactive fallout, and related issues.¹⁷⁸ The AEC and ACRS undertook safety research experiments on different reactor concepts. The incipient new private industry had a long way to go before reactor operations, even boiling water reactor operations then considered the most promising concept for commercial development, could be considered safe in locations other than isolated western deserts.

An early series of tests were the Special Power Excursion Reactor Tests (SPERT) that began in 1955. Originally conceived as a program to explore the operational limits of small study reactors used in university settings, the experiments moved on to evaluate the safety limits of other types of reactors as well. Testing reactors to their point of destruction continued the tradition established uniquely at the NRTS with the earlier BORAX experiments.¹⁷⁹

The SPERT experiments took place at a site built and operated by Phillips Petroleum Company about sixteen miles from the eastern NRTS boundary at a point where dominant winds would not carry radioactive materials across other activity areas at the NRTS in the event of a destructive reactor test. The site was a few miles northeast of the OMRE site and a few miles northwest of the Army's reactors.¹⁸⁰

Research examined the safety requirements of containment buildings and the behavior dynamics of reactors should their power levels change rapidly.¹⁸¹ A major objective was to postulate various kinds of "accidents" that could occur in a nuclear power plant, determine how the reactor would respond to them, and work out ways to control or prevent such accidents. Additional goals of the SPERT program were to design power plants with improved operational flexibility and at less cost.¹⁸²

¹⁷⁸ Richard Doan, "Two Decades of Reactor Safety Evaluation", Memorial Lecture in honor of Dr. C. Rogers McCullough prepared for delivery at the Winter Meeting of The American Nuclear Society in Washington, D.C. November 15-18, 1970.

¹⁷⁹ Stacy, *Proving the Principle*, p. 133-134.

¹⁸⁰ T.R. Wilson *An Engineering Description of the SPERT-1 Reactor Facility* (Idaho Falls: Report NO. IDO 16318), p. 8.

¹⁸¹ *Special Power Excursion Reactor Tests* (Idaho Falls: Phillips Petroleum Company, no date) no page. Hereafter cited as "Phillips, SPERT."

¹⁸² *Thumbnail Sketch* 1969, p. 31.

SPERT experiments began in 1955 and continued until 1970. A series of specially designed and instrumented reactors were deliberately operated beyond normal safety limits to answer the simple question, "What will happen?" The data that was gathered and analyzed throughout the period was used to help design commercial reactors.¹⁸³

The SPERT Control Area

The purpose of SPERT was to find basic explanations for reactor behavior under runaway conditions. The SPERT complex was therefore arranged so that the reactors could be controlled from a safe distance. The control building was located half a mile from the reactors in a fenced area 250 feet x 250 feet. This area also included a supply of raw water.¹⁸⁴ The Control Building (later converted to a conference room in PER-601) housed the SPERT-I reactor controls, administrative offices, instrument and mechanical work areas, and dark room. It included sufficient expansion space for the controls and instruments of the SPERT reactors that would follow in later experiments.

The Terminal Building was about 2,800 feet from the Control Building. It housed the service facilities for the reactor, including necessary water and air equipment and a personnel decontamination and change room. It was located such that additional SPERT reactors could be built on an arc having a radius of about 400 feet from the building.

SPERT-1

The SPERT-I experiment was located 3,000 feet northwest of the control building and included two adjacent structures -- the Reactor Building and the Instrument Bunker, the latter being an earth-covered concrete structure that housed relays and other auxiliary equipment for the reactor. The two buildings were enclosed within a fenced area 150 feet x 150 feet. SPERT-I tested reactor transient behavior and performed safety studies on light-water moderated, enriched-fuel reactor systems. SPERT-I went into operation June 11, 1955. It was a simple reactor, consisting of the core in an open tank of water.¹⁸⁵

¹⁸³ Phillips, *SPERT*.

¹⁸⁴ *Thumbnail Sketch* 1962, p. 31.

¹⁸⁵ During the start of the Spert project, water-cooled and -moderated reactors were the most common type of reactor in the United States, and tests would be of immediate value to reactor designers.

A plate-type, enriched uranium-aluminum core was placed into the open vessel. The assembly had no provisions for heat removal or coolant circulation through the core. Total energy released during the anticipated lifetime of the facility was expected to be small, so no special biological shield was installed. The tank was four feet in diameter by ten feet high.¹⁸⁶

The Reactor Building was a 24 feet x 18 feet galvanized iron structure which housed the reactor and associated equipment, electrical switchgear, and other auxiliary facilities. The structure was unimposing and built to afford the minimum required to protect personnel and equipment from extreme dust conditions and winter weather. The reactor vessel and tank were in a pit embedded in the floor. The pit had a drain and sump pump for automatic removal of waste water to a leaching pond outside the building. On the northwest side of the reactor pit, and also embedded in the building floor, were eighteen tubes used for the temporary storage of reactor fuel.

The Instrument Bunker was a 10 feet x 12 feet, earth-covered, concrete block structure. Openings for instrument and electrical leads entered the bunker from the Reactor and Control buildings. SPERT-I had two instrumentation systems, one for controlling the reactor and one for studying transients. Observers in the control room watched the reactor on closed-circuit television. The camera was mounted above the tank in the reactor building.¹⁸⁷

The SPERT-I reactor could produce bursts of high-energy neutrons for very short time periods. The reactor successfully demonstrated in 1958 that a safety device called a reactor fuse was capable of preventing a reactor runaway. The fuse worked independently of the mechanical control system and shut down the reactor by rapidly injecting a neutron absorbing gas into a chamber located within the reactor whenever the power level rose at an excessive rate.¹⁸⁸

The SPERT-I tests showed that the reactor typically shut down following a surge of power. But in some cases, instabilities were observed following the power peaks. These divergent oscillations would probably destroy the reactor despite its self-limiting characteristics if they were allowed to continue. Determining the precise causes of these oscillations in the face

¹⁸⁶ *Thumbnail Sketch* April 1958, p. 8.

¹⁸⁷ *Thumbnail Sketch* July 1962, p. 31.

¹⁸⁸ *Thumbnail Sketch* June 1961, p. 32-34.

of inherent shutdown tendencies in water reactors was one of the important research goals that justified the construction of additional reactors in the SPERT family. By 1960 SPERT-1 had been put through more than 1,000 tests using six different reactor cores.¹⁸⁹

More complex SPERT reactors were under design and construction after 1958. Knowing this, researchers felt they could take greater risks with SPERT-I tests. Beginning in November 1962 SPERT-I was deliberately destroyed in a test that simulated an extreme reactor accident. SPERT-I was decommissioned in 1964. All but the outer vessel of the reactor, which had internal contamination, was dismantled. The SPERT-I site was then occupied by the Power Burst Facility.¹⁹⁰

SPERT-III

Both SPERT-II and SPERT-III went under construction about the same time. But SPERT-III was ready for its initial criticality before SPERT-II. It consisted of a reactor vessel, a pressurizing tank, two primary coolant loops with pumps and heat exchangers. The reactor building consisted of the main section for the reactor and coolant systems and a wing for electrical switchgear, process controls, instrumentation, and other equipment. The main reactor building, a pumice-block structure, steel-girded, was 40 feet x 80 feet x 30 feet high. A ten-ton crane spanned the forty-foot width and served the entire length of the building. The reactor vessel was located below floor level in a pit centered twenty feet from the south wall. A process-equipment pit extended from the reactor pit to the north wall and was separated from the reactor pit by a concrete wall three feet thick.

The reactor was designed for versatility, allowing cores of different shapes and sizes to be placed in the vessel for investigation. To accommodate the different designs, the internal structure was easily removable and could be replaced by a structure that would accept a different core design. The reactor vessel and control rod drive could accommodate cores having a minimum active core height of 42 inches.¹⁹¹

¹⁸⁹ "SPERT-2 Features Versatility," *Nucleonics* (June 1960), p. 120.

¹⁹⁰ *Site Characteristics, Volume II, Site Development Plan*, 1983.

¹⁹¹ C.R. Montgomery, J.A. Norberg, and T.R. Wilson, *Summary of the Spert-I. -II. and-III Reactor Facilities* (Idaho Falls: AEC Report No. IDO-16418, November 1957), p. 25.

SPERT-III went critical on December 19, 1958, and continued to operate until the completion of its programmed operations in June of 1968. The first core in SPERT III was similar to some of the early SPERT-I cores, but the emphasis now was to vary the flow, temperature, and pressure of the coolant water in the reactor vessel to see what effect these had on excursions. The tests subjected plate-type fuels to a range of coolant temperatures and pressures, for example.

The results of the tests encouraged the nuclear power industry because they showed that operating a reactor under power-plant conditions did not significantly affect the self-shutdown of a reactor after an excursion. Beginning in 1965, SPERT-III tested another type of fuel, low-enriched uranium-oxide rods.¹⁹²

SPERT-II

SPERT-II achieved criticality March 11, 1960. This pressurized water reactor had cost \$4 million and featured removable fuel plates and variable coolant flow rate and direction. The system could use heavy or light water as a coolant. It had removable internal absorber shells so that the thickness of the reflector could be varied. SPERT-II tested various moderators and various core sizes.¹⁹³

SPERT-II tested the behavior of heavy-water-moderated reactors, a reactor concept that was important in Canada and potentially important in the United States.¹⁹⁴ The tests also studied the effects of neutron lifetime on power excursions. The reactor went on standby status in October 1964 after completing its program in August 1964.

SPERT-IV

SPERT-IV was built partly because the tank of SPERT-I was

¹⁹² *Special Power Excursion Reactor Tests* (Idaho Falls: National Reactor Testing Station, 1965), p. 31.

¹⁹³ "Second SPERT Reactor in Idaho Goes Critical," *Idaho Daily Statesman*, March 13, 1960.

¹⁹⁴ Only one heavy water reactor was built as a part of the Power Demonstration Reactor Program (PWDR). The Carolina Virginia Tube Reactor (CVTR) used heavy water as a moderator and coolant and operated from 1964 to 1967.

too small for further investigations of instability phenomena. Construction of the facility was completed in October 1961; initial criticality was achieved on July 24, 1962.¹⁹⁵

One of the important SPERT-IV activities involved the Capsule Driver Core (CDC), the testing of representative power reactor fuels to obtain information on the various mechanisms resulting in the destruction of reactor fuel. The information helped reactor designers provide safeguards needed to meet safety requirements. The CDC program at SPERT-IV ended in 1970.¹⁹⁶

Significance of SPERT

SPERT reactors at the NRTS carried out the major portion of the AEC's reactor safety program during the early part of the 1960s. They provided the nuclear industry with information needed to design and operate boiling water, pressurized water, heavy water, and open pool reactors. The work was essential in establishing the commercial nuclear power industry in the United States (and Canada.) The contributions of the program to the evolution of nuclear technology are a major reason for the significance of the NRTS in American history.

SubTheme: *Commercial Reactor Safety*
INEEL Areas: The SPERT/PBF and TAN Areas

The AEC Launches the Safety Test Engineering Program: PBF and LOFT

To explain the distinction among the AEC's many series of safety tests, J.A. Lieberman, AEC Assistant Director for Nuclear Safety, once said that SPERT tests had investigated "why" a reactor would behave abnormally, while the Safety Test Engineering Program (STEP) tests at the Power Burst Facility and Loss-of Fluid Test facility would examine "what" would happen to a reactor in a full-scale accident.¹⁹⁷

To find out "what" would happen, the experimenters originally conceived tests that would involve full-scale reactor

¹⁹⁵ R.E. Heffner, et al, *SPERT-IV Facility* (Idaho Falls: Report No. IDO-16745, no date), p. 2.

¹⁹⁶ *Special Power Excursion Reactor Tests* (Idaho Falls: National Reactor Testing Station, 1965), p. 42-44.

¹⁹⁷ J.A. Lieberman quoted in "AEC Plans Reactor-Safety Engineering Test Programs," *Nucleonics* (February 1963), p. 19.

systems and accidents. STEP was planned as a two-phase program. One phase -- the PBF -- would involve oxide core destructive excursion tests to be conducted in an open tank and in a closed pressure vessel. SPERT I, south of TAN, would be modified for the this phase.

The other phase would consist of the LOFT project and take place at the Flight Engine Test facility (FET) at TAN. New facilities would be constructed and some existing facilities modified and adapted.¹⁹⁸ This phase would simulate loss-of-coolant (or loss-of-fluid) accidents, in which a coolant pipe would rupture. The test would deliberately initiate a rapid accumulation of heat in the reactor core and cause a subsequent release of fission products from the melting fuel. This accident was considered highly improbable to occur in a commercial reactor, but nevertheless it was posited as a worst-case accident and referred to as the "maximum credible accident."

The Power Burst Facility (PBF)

The PBF program advanced beyond the capabilities of the SPERT reactors. It was equipped to examine in great detail how fuel reacted under accident conditions. The reactor produced intense bursts of power capable of melting (and thus destroying) samples of fuel without damaging the rest of the assembly. A loop carrying pressurized water through the core of the PBF reactor permitted the testing of irradiated fuel samples containing highly radioactive fission products in a controlled environment.

The research and experiments conducted during these programs extended the information base upon which safety criteria, procedures, and regulations were developed. The PBF was scheduled for a series of forty tests.¹⁹⁹

Construction of the PBF complex began near the old SPERT-I site on October 1965 and was completed in October 1970.²⁰⁰ The single-story PBF Control Center building, made of pumice block, was located at the SPERT-I control area. The reactor console was in this building. The Reactor Building, about half a mile from the control building, was 119 feet x 82 feet and had two annex

¹⁹⁸ "Test Area North," Nuclear News, May 1969.

¹⁹⁹ Power Burst Facility (Idaho Falls: Prepared for the U.S. Department of Energy's, Idaho Operations Office by EG&G Idaho, Inc. no date).

²⁰⁰ SPERT-I was decommissioned in 1964.

wings, a main reactor room, basement, and a sub-reactor room.²⁰¹

The complex included a variety of support and auxiliary buildings, including a well house, substation, fabrication and development building, storage warehouses, emergency generator building, and others. Many of these buildings remain in use. Additional buildings were constructed in the PBF area after the PBF experiments ended and mission of the PBF area changed.

The PBF had an open-tank reactor vessel, a driver core region where the test fuel was located, and a loop coolant system. The loop coolant system provided temperatures and pressures typical of pressurized water reactors. The water in the open pool provided cooling. The main core, usually referred to as the driver core, was fueled with 18.5% enriched uranium-235 contained in approximately 2,400 fuel rods, grouped in assemblies containing 28 to 64 rods each.²⁰²

PBF achieved its first criticality on September 22, 1972. Subsequent experiments supplemented the tests carried out in the LOFT phase of the program. The Power Burst Facility shut down after completing its mission. It is currently inactive.

Significance of the PBF

The PBF was a one-of-a-kind facility. It was the only reactor in the world where severe fuel rod burst tests were performed, where rapid power changes were performed on the order of milliseconds, and where loss-of-coolant accidents could be simulated within a special assembly that fit inside the main reactor core. Like the SPERT series, it advanced the safety of commercial power reactors.

Loss-of-Fluid Test (LOFT)

The Loss-of-Fluid Test was commissioned in 1962 when Congress authorized \$19.4 million for the project.²⁰³ The Phillips

²⁰¹ A.A. Wasserman, et al, *Power-Burst Facility (PBF) Conceptual Design* (Idaho Falls: Phillips Petroleum Report No. PTR-590, no date).

²⁰² *Power Burst Facility* (Idaho Falls: EG&G), n.p.

²⁰³ *A Historical Brief of the LOFT Project at the Idaho National Engineering Laboratory* (Idaho Falls: Aerojet Nuclear Company, December 1975), p.1. Hereafter cited as "*LOFT Historical Brief*."

Petroleum Company was the major contractor when construction started in the fall of 1964. The original plan for LOFT was to study a single, full power, loss-of-coolant accident that would cause a full melt down of the reactor core. The concept for the test was the question: "What is the life of all the components of a commercial reactor and how good are they?" Components included the pumps, valves, pipes, conversions to power, and all the other gadgetry involved in a reactor. A fair test was thought to require a full-scale model of a commercial reactor using commercially available components, not the highly engineered and specialized components used by engineers doing research.

The experiment was scheduled for completion in 1967, but the project was redirected and changed several times because of debates in the nuclear industry about what kind of testing would be most useful and valuable. Eventually, it was decided that a test of safeguards intended to prevent a loss-of-coolant accident would be more valuable than a test of components, for which other testing techniques had arisen. Revising the test objective required time to modify the designs. By 1968, all construction had stopped in order to await redesign instructions. Frequent stop-starts caused by design lags, contractor problems, changes in management, the need for more funds from Congress, a labor strike, and other problems, occurred until the summer of 1976, when the facility was at last ready to have the core loaded into the reactor.²⁰⁴

LOFT employed a scaled-down model (50,000 thermal kilowatts, one-fiftieth the size of a commercial reactor) of a commercial power reactor. It was placed inside a steel-and-concrete containment building (TAN-650) located just east of the ANP's hangar control building (TAN-630). The experiment was mounted on the Mobile Test Assembly (MTA), a dolly pulled by a shielded locomotive over the four-track rails, so it could be shuttled between the containment building and the TAN Hot Shop for post-test analysis. (In actual practice, however, the LOFT reactor was not moved in and out of the building.) LOFT also required a service building, control and equipment building, large storage building, radioactive waste tank building, electrical equipment, water wells, a liquid waste disposal pond, and other support facilities.²⁰⁵

In conjunction with the revamped LOFT project, non-nuclear tests known as "semiscale" were underway elsewhere at TAN. The

²⁰⁴ See *LOFT Historical Brief*.

²⁰⁵ For a full description of the planned LOFT site see *Preliminary Site Evaluation Report LOFT Facility PTR-544*, Phillips Petroleum Company, 1963.

semiscale apparatus consisted of a small reactor mock-up equipped with an emergency core cooling system (ECCS). (An ECCS was a system intended to flush coolant into a reactor core in the event that an accident interrupted the flow of the normal coolant.) Previous tests had suggested that water in the ECCS did not circulate as designed. Critics of the nuclear industry argued that the tests proved that emergency cooling systems would not work and that commercial reactors were at risk of releasing catastrophic amounts of radioactivity to the environment. The semiscale tests thus became part of the national debate over the safety of commercial nuclear power plants.²⁰⁶

Each LOFT experiment required time to construct and set up. The reactor vessel was installed on the MTA on November 6, 1972; the steam generator was set in place in December. In November 1973, the MTA moved into the LOFT containment vessel. During 1975, workers conducted functional testing of the LOFT systems. Non-nuclear large-break loss-of-coolant accidents (known as the L-1 series) took place from 1976 to 1978. At last, LOFT's first nuclear experiment began at the end of 1978 and continued into 1979 and 1982 as the L-2 series of nuclear large-break loss-of-coolant accidents.²⁰⁷

The containment building was a new domed building. Its substantial 200-ton doors were ready to withstand the force arising from a flash to steam when coolant was withdrawn from the reactor core. To begin the first simulation in December 1978 scientists opened a valve to imitate a "large break" in the cooling pipe. It was over in thirty minutes. The scientists learned that water flowed into the reactor vessel faster than it was expelled in the crucial first seconds after the "break," which kept the core cooler than they had expected.

Before a second test could be arranged the following May, an accident at a commercial nuclear power plant at Three Mile Island (TMI) in Pennsylvania caused a partial meltdown of the reactor core. LOFT scientists altered their work schedule and used their models (Semiscale) and computer programs to help determine how a potentially dangerous hydrogen bubble inside the TMI reactor could be dissipated. When the crisis was over, LOFT returned to its own test program, but as a result of TMI accelerated its study of "small breaks." The TMI experience had demonstrated that these, combined with the inappropriate intervention of human

²⁰⁶ U.S. Department of Energy, *Human Radiation Experiments: The Department of Energy Roadmap to the Story and the Records* (Washington, D.C.: Assistant Secretary to Environment, Safety and Health, February 1995), p. 96.

²⁰⁷ LOFT Historical Brief.

operators, potentially could be as dangerous as larger coolant-flow breaks.²⁰⁸

In 1982 federal financing for the LOFT experiment ran out after thirty tests. An international consortium arranged to fund several more tests, including the last one in 1985, when scientists tried to simulate the TMI accident and melt the core. The test (numbered LP-FP-2) was performed with a specially insulated center fuel module that was the subject of the test. The main core was set up as a driver core, which created the desired experimental environment in a central fuel module. The center fuel module was the only portion of the core that simulated the "small-break" loss-of-coolant accident that occurred at TMI. The driver core of LOFT did not melt, nor did it experience conditions much different than normal operating conditions. The temperature rose to 4,000 degrees F., but the core did not melt. The safety system operated to flood the core and cool it off. After the analysis of this last experiment, the LOFT program ended in 1986.²⁰⁹

Significance of LOFT

The significance of the LOFT tests can hardly be overstated in the history of the nuclear power industry. A coincidence of historical timing linked the long-planned tests of reactor safety with the real-world accident at the TMI plant. The final LOFT tests validated the effectiveness of the safety systems that had been built into the TMI and other nuclear power plants.

The buildings associated most importantly with LOFT are the containment building (TAN-650) and the aluminum building (originally made to protect the ANP reactors from the weather) recycled as an entry into the containment building (TAN-624). The LOFT building should be preserved in place as an exceptionally significant part of American nuclear history.

SubTheme: *Commercial Reactor Safety*
INEEL Area: *Experimental Dairy Farm*

Studying the Effects of Radioactive Fallout: 1957-1970

²⁰⁸ Bob Passaro, "TAN has Colorful, Secretive Past, to be mothballed by 2000," *Post Register*, May 15, 1994, p. H-12. The damaged core and tons of other contaminated waste from TMI was sent to the Site for analysis and study.

²⁰⁹ Stacy, *Hangar HAER*, p. 62.

Not all nuclear research at the NRTS took place at reactors. With the growing frequency of the destructive types of tests done at SPERT, the Health and Safety Division of the AEC's Idaho Operations Office felt it would be wise to understand the potential health impacts of the radioactive releases that accompanied such tests. In the event of a large accidental release, the NRTS wished to be prepared with a plan of action aimed at protecting site employees and persons off-site and downwind of the release.²¹⁰

The Health and Safety division initiated a program called Controlled Environmental Radioiodine Tests (CERT). Related issues and concerns included the potential impact of radioactive releases at nuclear power plants operating at normal conditions. At the time little was known about such effects. Even less was known about the impact of accidental releases. The CERT program used radioactive Iodine-131, one of the release products in destructive reactor tests, and gathered data on how it moved through the food chain in areas on and adjacent to the NRTS.

The Health and Safety Division already had previous experience during the early 1950s monitoring radioiodine in wildlife, natural vegetation, and on nearby farms and ranches. A number of studies had been made on the local jackrabbit population. In 1958 thyroid measurements were taken from two goats pastured near the Chemical Processing Plant (discussed below) for several days. The CERT program extended these studies, collecting its data under more controlled conditions.

The experiments involved releasing clouds of radioiodine over specific locations to answer certain questions. For example, the first tests examined what percentage of the radioiodine accumulated in the soil, grasses, and other vegetation and what percentage drifted off into the airshed. Then, when cows grazed on the grass, what percentage of the radioiodine was excreted and how much went into the cow's thyroid or milk. A final question involved determining what percentage of the material would end up in a human thyroid after drinking the cow's milk.²¹¹

²¹⁰ Stacy, *Proving the Principle*, p. 167.

²¹¹ John R. Horan, editor. *Annual Report of the Health and Safety Division, Idaho Operations Office* (Idaho Falls: 1958), p. 95; D.F. Bunch, editor. *Controlled Environmental Radioiodine Tests, Progress Report Number Three* (Idaho Falls: Health and Safety Division, Idaho Operations Office, US AEC Report IDO-12063 1968), p. 2-4; *Human Radiation Experiments: Department of Energy Roadmap to the Story and The Records* (United States Department of Energy, Assistant Secretary for Environment, Safety and Health Report No. DOE/EH-0445, February 1995.)

To gather data on the human thyroid, the experiments had to involve volunteers who would drink the milk and then be measured for the iodine. The first experiment using cows and humans was conducted in May and June of 1963. Because permanent facilities were not yet available, CERT I took place on the "open range," an unirrigated section of land near the southern boundary of the NRTS. A temporary barn, corral, and control trailers were placed in the area on temporary foundations. Two pasture areas were established, one "hot," or radioiodine-contaminated and one "cold," where the cattle could be grazed prior to the experiment. Seven human volunteers drank the contaminated milk. Their thyroid activity was measured over a six-week period.²¹²

The Experimental Dairy Farm, located about seven miles northeast of the ICPP, was built during the summer of 1963. The site was selected for its location relative to reactors and roads, water availability -- an adequate well already existed -- and because the land was unused and available. The farm was intended to duplicate regional farming methods. Facilities included a dairy barn, pumphouse, sprinkler system and corral. A twenty-seven acre pasture was established, and grass seed was planted.

The CERT experiments waited until the following September when the grass had matured. Six cattle were again grazed on the hot pasture following the release of radioiodine. Humans again participated in drinking contaminated milk. Related experiments measured thyroid activity following inhalation of I-131 by three people who sat in the pasture as the radioiodine cloud passed over it.²¹³

Later experiments measured radioiodine deposits and dispersion under various weather conditions and in different seasons or times of day. In 1967 the experiments were modified to provide more detailed information. Stalls built in the barn allowed individual monitoring of each cow's water and feed. Careful measuring of feed and use of a "chopper" allowed more accurate measurement of iodine dosage than was possible when cattle grazed freely. These refinements reflected the growing

²¹² C.A. Hawley, et al, *Controlled Environmental Radioiodine Tests, National Reactor Testing Station* (Health and Safety Division, Idaho Operations Office, US AEC Report NO. IDO-12035, 1964), p. 2-10; C.A. Hawley, editor, *Controlled Environmental Radioiodine Tests at the National Reactor Testing Station, 1965 Progress Report* (Health and Safety Division, Idaho Operations Office, US AEC Report No. IDO-12047, February 1966) p. 2.

²¹³ Hawley, IDO-12047, p. 4-5.

sophistication of the investigation.²¹⁴

The CERT program contributed to the worldwide efforts of scientists to learn more about the environmental effects of nuclear power plant operation. Previous studies at Hanford, Washington, and Oak Ridge, Tennessee, had provided some information about the dispersion of radioiodine, but the field and laboratory studies at the NRTS were more comprehensive. They provided data for computer models that predicted the transfer of iodine through the food chain to milk and subsequently as doses to human beings. The CERT study helped, in fact, to illuminate the key role of the food chain in the transfer of radioiodine and other substances. CERT data laid a basis for understanding the impacts of releases that might occur after an accidental release. CERT provided some of the most comprehensive and useful data available in the United States or anywhere else. The findings, in conjunction with data from other studies, helped scientists realize that the allowable releases of radioactive materials from nuclear power plants had to be reduced. CERT studies eventually led to regulatory changes reducing such discharges from light-water reactors.²¹⁵

Two buildings related to CERT are extant, the barn (B16-603) and a pumphouse (B16-604). The barn has been converted for use as a storage building. They are a remnant of a frontier-like period in nuclear research when the impact of radionuclides on human health through the food chain and direct inhalation involved people and animals, helping to set parameters for future computer modeling, commercial reactor operations, and emergency planning.

²¹⁴ J.D. Zimbrick and P.G. Voilleque, editors, *Controlled Environmental Radioiodine Tests at the National Reactor Testing Station, Progress Report Number Four* (Health and Safety Division, Idaho Operations Office, US AEC Report NO. IDO-12065, January 1969), p. 2, 5.

²¹⁵ J. Newell Stannard, *Radioactivity and Health, A History* (Hanford, Washington: Pacific Northwest Laboratory, 1988), p. 1358.

SubTheme: Chemical Reprocessing
INEEL Area: Idaho Chemical Processing Plant

Establishment of the Chemical Processing Plant: 1949-1954

The Idaho Chemical Processing Plant (ICPP, or Chem Plant) was designed by the same group of physicists and chemists who had designed the MTR. As a companion facility for the MTR, it was equipped to receive the MTR's spent fuel elements and extract valuable U-235 from them. The spent fuel contained radioactive elements such as Strontium-90, Cesium-137, and other substances dangerous to human life. At the end of extraction process, the ICPP shipped the recovered U-235 to Oak Ridge, Tennessee, for further steps leading to the remanufacturing of fuel elements. The uranium was not a hazard, but the ICPP had to store or otherwise dispose of the dangerous materials left behind.²¹⁶

The ICPP was one of the four original areas developed at the NRTS. Although its originators conceived it as an auxiliary to the MTR -- to recover the uranium in its highly enriched fuel -- its mission expanded to include processing of spent fuel from other sources. With the escalation of tensions between the United States and the Soviet Union, aggravated by the Korean War, the AEC shifted the majority of its resources to developing atomic weapons. The plutonium-producing reactors at Hanford, Washington, sent some of their spent fuel to Idaho.²¹⁷

During normal operations, the MTR shut down every 17 days to remove its depleted fuel. By this time, less than a fourth of the U-235 had fissioned, leaving a substantial amount of U-235 in the fuel elements. Rather than discarding this costly material, it was possible to extract it from the aluminum cladding and other substances that had accumulated in the fuel in order to re-use it for new fuel elements.²¹⁸

Establishing the Chem Plant required hiring and training its operators and then running "cold" operations with simulated waste to test the facility. After that, the first hot runs began processing spent Hanford fuel on February 16, 1953, with fewer than 100 employees.²¹⁹

²¹⁶ The ICPP was renamed Idaho Nuclear Technology and Engineering Center (INTEC) in 1999. This report will use the historic name.

²¹⁷ Stacy, *Proving the Principle*, p. 94-97.

²¹⁸ Stacy, *Proving the Principle*, p. 69.

²¹⁹ Stacy, *Proving the Principle*, p. 101.

The Modified PUREX Process

Uranium was extracted from the fuel elements in a multi-step chemical treatment process known as a modified PUREX (Plutonium and URanium EXtraction) process. (The PUREX process had been developed during the Manhattan Project.) The fuel was dissolved in a solution of nitric acid. This liquid then was "run" by steam-jet suction through three extraction processes or "cycles," in which chemical additives, catalysts, and mechanical actions produce a sequence of chemical reactions resulting in the separation of uranium from the other metals, acids, and fissionable products in the solution. "Waste" products -- solids, gases, and liquids -- accumulated upon completion of each cycle. The uranium product was then shipped to Oak Ridge, where it was further prepared for remanufacture into new fuel elements.²²⁰

Siting and Designing the ICPP

The ICPP was located to be convenient to the MTR and to the CFA. Initially consisting of 82 acres, the plant was located about three and a half miles north of the Central Facilities Area and on the east side of Lincoln Highway. The TRA is another mile and a half further northwest on the west side of the highway.

The Foster-Wheeler Company designed the plant. The Bechtel Corporation built it. The first operating contractor, American Cyanamid, managed construction, recruited and hired operating personnel, and developed the first operating manuals. On October 1, 1953, Phillips Petroleum Company took over the plant and continued managing it until 1966, the first in a series of five operating contractors.²²¹

The plant buildings were contained mostly within the

²²⁰ For a more detailed description of the ICPP's modified PUREX process, see Brewer F. Boardman, *The ICPP (A Factsheet)* (Idaho Falls: Idaho Operations Office, 1957). For a general description of the plant and its operations, see R.B. Lemon and D.G. Reid, "Experience With a Direct Maintenance Radiochemical Processing Plant," *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Volume 9* (New York: United Nations, 1956), p. 532-545.

²²¹ Succeeding operators were Idaho Nuclear Corporation, 1966-1971; Allied Chemical, 1971-1979; Exxon Nuclear Corporation, 1979-1984; Westinghouse Idaho Nuclear Corporation, 1984-1994; Lockheed Martin Idaho Corporation, 1994-present.

rectangular perimeter boundaries of a security fence. By no means did these consume the entire 82 acres; the designers planned for growth and expansion. Today the perimeter fence encloses 210 acres, and an additional 55 acres lie outside the fence.²²²

One way to identify the main features of the site is to follow a shipment of fuel as it arrived at the ICPP gate. The fuel arrived packed in heavily shielded transport casks carried in specially equipped carrier trucks or by rail. After passing through the main guard gate at the west side of the plant, the truck headed south about a third of a mile away to CPP-603, the Fuel Storage Facility, isolated from the main activity area for safety. The truck entered special bays for the transfer operation. Unloading of the fuel to one of two transfer basins was handled remotely. The fuel elements were placed in stainless steel buckets, suspended from overhead racks, and the whole apparatus placed in a water-filled basin. At least 15 feet of water was above the submerged fuel at all times. This water was recirculated and refreshed daily, the overflow going to a percolation pond just to the south of CPP-603 and on the outside of the perimeter fence. The Fuel Storage Facility had its own heating and air cleaning system and its own generator for emergency power supply. Water came from the main plant source, but was metered and filtered with separate equipment. The structural steel building was covered with Transite siding. Before arriving at the ICPP, the fuel typically had had at least 90 days of cooling time. Here it cooled off for another 120 days or more.

When the proper time had elapsed and the operators had accumulated sufficient fuel to "run" the extraction process at the Fuel Processing Complex (CPP-601), a "straddle carrier" transferred the fuel to the "head end" (south end) of CPP-601. The first step was to dump the fuel element into a vessel of nitric acid to dissolve it -- cladding, fuel, and all. From there it went via a complex system of piping from one process cell to another, each step producing various waste products. Each product in this waste stream required treatment before it could be released to the atmosphere or stored. All vessels and piping were sized (small) to prevent the accidental accumulation of a critical mass of fissionable fuel.

The process complex was designed for direct maintenance. This meant that during periodic shutdowns, workers could decontaminate work areas and perform maintenance tasks on the equipment. A minimum of moving parts made for simplicity, although essential items such as transfer jets, valves, and pumps

²²² "Land Use Information, www.inel.gov/resources/flup/icpp.html.

were installed in pairs, one being a spare. High-maintenance equipment was placed in crew-accessible lead-shielded cubicles outside the hot process cells. Cleaning solutions were sprayed into the cells, flushed out, and then entered by maintenance personnel via ladders.

The portion of the building above grade contained no uranium-processing equipment. It was constructed of steel framing and insulated with Transite siding. Chemicals added to the process feed were stored in tanks on this level.²²³

Waste products left the process building in underground pipes eastward to the Waste Treatment Complex, which included three main waste processing buildings and a tank farm. One of the buildings (CPP-604) housed the equipment necessary to recover Krypton-85 gas and generally reduce the volume of waste. Another (CPP-605) housed blowers which provided vacuum to process cells and exhausted filtered off-gases to the 250-foot tall main stack (CPP-708). The Complex recovered all of the nitrogen and oxygen needed at the ICPP and other parts of the NRTS site. Further east of the Waste Complex -- downwind of operations -- was the 250-foot stack.²²⁴

North of the Waste Treatment Complex is the Waste Tank Farm, constructed in 1953. Buried here were two 300,000-gallon stainless-steel tanks for storing high-level radioactive liquid wastes. Each was enclosed in a concrete vault and buried under ten feet of earth. One tank, which received the very "hot" first-cycle waste, was equipped with cooling coils; the other was not. A large empty area was left near these two tanks for future expansion. This restricted area contains structures housing instrumentation for monitoring the contents of the tanks.

The rest of the site was developed to complement and serve the main process. A laboratory and administrative building (CPP-602) adjoined the process building on the north. This building contained offices, cafeteria, health physics services, first-aid facilities, low-level and high-level laboratories, and a machine shop. A service building (CPP-606) at the north side of the laboratory housed the steam plant, electrical equipment, and ventilating equipment for the laboratory buildings. This too was built of structural steel and sided with Transite. Outside the

²²³ The progress of fuel to be reprocessed is extracted from "Chemical Processing of Reactor Fuel Elements at the Idaho Chemical Processing Plant," *Proceedings of the Geneva Conference* (New York: United Nations, 1955), reprint pages 14-23.

²²⁴ R.D. Logan, *INEL Building Study, Idaho Chemical Processing Plant* (Idaho Falls: INEL Energy Management, 1990), p. 33-36.

perimeter fence on the northeast side was the sewage lagoon for sanitary wastes.²²⁵

As the ICPP was designed to be a "multi-purpose" plant, it was adapted from time to time to improve or perform specialized functions. One of them was the recovery of radioactive Barium from day-old MTR fuel. The L Cell in CPP-601 -- with extra thick concrete shielding -- contained centrifuges and other equipment related to this process and also to the handling of the off-gas byproducts. The researchers hoped to find a way to precipitate only the target element from a more complex solution. A Fuel Element Cutting Facility was attached to CPP-603 near the railroad siding to aid in the handling of fuel casks and fuel elements.²²⁶

The operation of the plant and its processes required substantial quantities of water. This was pumped from the Snake River Plain aquifer into two 500,000-gallon storage tanks at the north end of the site. As needed, water was demineralized or otherwise treated depending on its particular use.

The Role of the ICPP in the Cold War

As the Cold War and the arms race progressed, the United States poured its resources into weapons development, striving to assure its supremacy. Elsewhere in the country, the AEC's plutonium-production reactors were expanding. At the NRTS, all research missions bent to the compelling needs of national defense. From its original mission of reprocessing only MTR and Hanford fuel, the ICPP was adapted for more flexibility as a multiple-purpose processing plant. Eventually, it would process fuel from a wide variety of research, test, propulsion, and power reactors. In addition to aluminum clad fuels, it would dissolve fuels clad in zirconium, stainless steel, and other materials. It handled fuel from EBR-1, BORAX, and other experiments around the NRTS site.²²⁷

ICPP Adds New Processing Functions: 1955-1970

By the deliberate effort of Congress and the AEC, the supply

²²⁵ "Chemical Processing of Reactor Fuel Elements at the Idaho Chemical Processing Plant," *Proceedings of the Geneva Conference* (New York: United Nations, 1955), reprint p. 19

²²⁶ *Thumbnail Sketch* 1956, p. 6.

²²⁷ *Thumbnail Sketch* November 1958, p. 15.

of spent fuel was destined to grow as a consequence of reactor development. Congress passed the Atomic Energy Act of 1954, and the AEC and Congress's Joint Committee on Atomic Energy did what they could to nurture a commercial atomic power industry. The US Navy launched the USS *Nautilus* submarine in the 1950s and then built a large fleet of ships propelled by nuclear reactors. Shippingport, an AEC demonstration reactor, went on line in Pennsylvania in 1957, the first large reactor to be built for civilian purposes. Research programs at the NRTS tested the safety limits of reactor fuels and core constructions. General Electric and Westinghouse scaled up the demonstration and began to sell reactors to electric utility companies. A commercial industry began to grow. Clearly, this success meant that spent fuel would need reprocessing.

With every processing run at CPP-601, a stream of high-level waste inevitably flowed into the stainless steel tanks at the ICPP tank farm. After the first one was filled, another was made ready, and then another. By 1960, 13 tanks populated the ICPP's tank farm. Nine 300,000-gallon vessels held aluminum-type wastes; the other four each held 30,000 gallons of zirconium and stainless steel. Awash in a million gallons of liquid were only ten gallons of radioactive material.²²⁸

Scientists knew that metal tanks could not serve as a long-term method for storing the waste. They regarded the life of a stainless steel tank to be no longer than 50 years because the acids from within or moisture from without would eventually corrode the metal. The hazard they wished to avoid was to have the radioactive liquid leak into surrounding soils and ground water. Far more than 50 years were required to sequester the waste -- several centuries would have to elapse before the process of radioactive decay could reduce the hazard potential significantly.²²⁹

Chemists in the AEC's national laboratories therefore launched investigations into "interim" and "ultimate" disposal of these wastes. One of the concepts for dealing with the growing volume of liquid waste was to transform it somehow into a dry

²²⁸ To Senator Henry Dworshak from John B. Huff, August 21, 1958; Senator Dworshak Papers, Box 83, File "AEC--Idaho Plant." Also, "Idaho Falls: Atoms in the Desert," *Chemical Engineering* (January 25, 1960), p. 5 (of reprint.)

²²⁹ The half-life of Strontium-90 is 29 years; of Cesium-137, 30 years. A half-life is the time required for one-half of the atoms of a radioactive substance to disintegrate. The process is independent of temperature, pressure, or surrounding chemical conditions.

solid, eliminating the water. This meant designing a process that would concentrate radioactive substances into a dry form, leaving the water clean enough to discharge into the environment. This could be an "interim" step in storing the waste. The volume could be reduced and the hazard of corrosion and leakage minimized. It was also conceivable that the solid form might be rendered even more inert or stable using processes as yet unproven.

Scientists proposed several ideas for transforming liquid into an inert solid-carrier waste. A 1954 study from Brookhaven National Laboratory suggested that radioactive ions could be made to adsorb and fix upon montmorillonite clay. Other studies proposed fixation in ceramic glazes or "gelling" liquids above the sludges that form in the tanks. Various techniques for solidifying the waste included pot calcining, radiant heat-spray, and rotary-ball kilns. Some proposed to incorporate the wastes into low-melting salts and store the material in underground salt caverns equipped to remove heat. Another optimistic hope was that some breakthrough chemical means of decontaminating the radioactive constituents might be found. At Oak Ridge National Laboratory, workers were investigating the possibility of mixing waste with shale, limestone and soda ash and allowing decay heat to fix the material in a ceramic mass. Still other proposals sidestepped the problem altogether and proposed to discharge it into the oceans or outer space.²³⁰

The Waste Calcining Facility (WCF)

The first liquid-to-solid procedure that the AEC decided to fund for actual demonstration, however, was the "fluidized-bed calcination process," built at the ICPP. The development program began in 1955. Originally conceived by scientists at Argonne National Laboratory, the method was first tested using small-scale models and then built by Phillips Petroleum at the ICPP. The process not only solidified the waste, but the solid was granular, free-flowing, and easily handled by pneumatic transport techniques. Phillips engineers proposed early conceptual designs

²³⁰ See W.S. Ginnell, J.J. Martin, and L.P. Hatch, "Ultimate Disposal of Radioactive Wastes," *Nucleonics* (December, 1954), p. 14-18; "Outlook for Waste Disposal," *Nucleonics* (November 1957), p. 155-164; *The Waste Calcining Facility at the Idaho Chemical Processing Plant*, pamphlet, no date, no author, p. 2; Joseph A. Lieberman, "Treatment and Disposal of Fuel-Reprocessing Waste," *Nucleonics* (February 1958), p. 86; and J.I. Stevens, et al, *Preliminary Process Criteria and Designs for Waste Calcining Facilities at the Idaho Chemical Processing Plant* (Idaho Falls: Phillips Petroleum Company Report No. PTR-177, February 25, 1957), p. 5.

for the process in 1956.²³¹

The concept of fluidized bed technology was not new. It had been applied in the petroleum, iron and steel, and limestone industries. As applied to liquid radioactive wastes at the WCF, it involved placing a bed of sand-like granular material at the bottom of a cylindrical vessel -- the calciner vessel. The grains are then heated to temperatures of 400 degrees C or more by a heat exchanger placed directly in the bed. A flow of hot air was introduced into the bed through fourteen holes at the bottom of the vessel and evenly distributed to the grains, placing the grains in motion, or "fluidizing" them. Liquid waste was fed as a fine mist into the vessel by pneumatic atomizing spray nozzles. In the hot environment, the water vaporized and the solids adhered to the small starter grains tumbling around in the fluidized bed. As the process continues, the solids knock against each other, causing particles to flake off and form the starter grains for the continuously sprayed liquid feed.

Congress appropriated funds in 1957 for the early phases of the WCF design. The AEC awarded a contract to Fluor Corporation to be architect/engineer for the project. In 1958, the AEC asked Fluor to complete and construct the system. The facility cost about \$6 million. Fluor commenced construction in 1958 and completed the facility in 1961. Phillips took control of the building and began two years of "cold" trouble-shooting operations using simulated waste.²³² Hot operations began with the first run, called a "campaign," on December 23, 1963.

The WCF expanded the ICPP area to the east. The building (CPP-633) was placed southeast of the stack, where room still further east was available for the special tanks that would store the calcine. The building handled the entire process, receiving its fluid feed from underground piping extended from the main process building. The dry calcine -- called *alumina* -- exited the

²³¹ See C.E. Stevenson, et al, *Waste Calcination and Fission Product Recovery Facilities--ICPP, A Conceptual Design* (Idaho Falls: Phillips Petroleum Company Report PTR-106, August 2, 1956); and D.R. Evans, *Pilot Plant Studies with a Six-Inch Diameter Fluidized Bed Calciner* (Idaho Falls: Phillips Petroleum Company Report No. IDO-14539), p. 2.

²³² News release from Idaho Operations Office of the AEC, February 5, 1957; Senator Dworshak Papers, Box 74, File "Legislation--AEC--Idaho Releases." See also "Fluor Gets Contract to Complete Calcination System," *Nucleonics* (November 1958), p. 27; and L.T. Lakey, et al, *ICPP Waste Calcining Facility Safety Analysis Report* (Idaho Falls: Phillips Petroleum Company Report No. IDO-14620, 1963), p. ii-1.

facility propelled by pneumatic pressure to storage facilities called "bin sets" about a hundred feet east of the building.

Each bin set contained from three to seven vertically positioned stainless steel tanks. Partially above grade level, they were shielded by an earthen berm. On top of each bin set was an "instrument shack" and other devices designed to monitor the accumulation of waste heat and detect leaks or other problems. Seven bin sets have been constructed at the site. Experience with calcine led to modifications of the earliest bin set design. It was not known just what products in the solid might prove to have future value, so the storage containers were designed so that the calcine could be retrieved for some future purpose. All operations had to take place so that radioactive particles could not enter the air or water supply.²³³

The over-riding imperative guiding the design of any process dealing with hazardous radioactive waste is to protect workers from danger. The calcining building followed the same principles that had been implemented in the design of the Fuel Processing Complex (CPP-601). Process equipment was decontaminated using automated methods, and then maintained "directly" by crews. Radioactively hazardous areas were located below grade, while the non-radioactive service areas were on the ground floor.

The WCF building contained everything required for the calcining process except for the tanks that stored fuel oil and the bins that would store the calcined product. Filtered off-gases went up the main stack, and other wastes were sent through the calciner along with the fresh liquid feed.

The ICPP Operating Routine

With the calciner the ICPP had two major chemical processing operations underway. Phillips established a routine whereby the two processes alternated their "run" operations. While the main processor operated, a crew decontaminated and maintained the calciner. Likewise, when the calciner ran, the main processor was shut down for repair and cleaning. A traveler on Highway 20, just outside the NRTS site, could always tell when the calciner was operating because the stack exhausted an orange-yellow plume of nitric oxide gas, a byproduct of the calcine operation.

A range of laboratories complimented the site. In analytical laboratories, chemists routinely examined samples of solutions from various stages of chemical processing. They checked for uranium isotope content, acidity, and other parameters. To

²³³ PTR-177, p. 7-8.

accommodate the type of analysis required, laboratories were "hot," "warm," or "cold," and designed accordingly. In addition, some laboratories were devoted to "wet" chemistry, examining primarily liquid solutions. Equipment such as mass spectrometers and x-ray devices sometimes required special enclosures or shielded cells.

Meanwhile, in the ICPP laboratories, chemists and engineers conducted tests and studies aimed at increasing the productivity and effectiveness of each process. One of the problems with the calciner, for example, was that the fluidized bed was heated by means of a circulating loop of NaK, a sodium-potassium eutectic alloy. Unplanned plant shutdowns frequently occurred because of leaks in the NaK piping. In 1970, in time for the calciner's fourth campaign, the NaK system was replaced by a direct combustion system. Engineers refitted the calciner vessel so that kerosene and oxygen could be sprayed into it. Nitrates from the waste feed would ignite it, placing the heat in intimate contact with the moving particles in the bed. This method supplied steady temperatures of 450 degrees C. Overall, the new system was less hazardous because hydrocarbon fuel piping was more reliable than NaK piping.²³⁴

Other improvements took place at the main process facility. Better headend equipment was installed for "cutting" fuel elements, reducing the amount of non-irradiated metal cladding dumped into the acid dissolver. A railroad track was built between the ICPP and the Naval Reactors Facility to facilitate the transfer of USS Nautilus and other fuels from that area.²³⁵

By 1959, the ICPP was engaged in a joint project with the United States Geological Service to monitor the aquifer downstream of the ICPP injection wells, into which the plant pumped low-level liquid wastes. Fifteen such wells sampled water downstream.

Failure of Commercial Processing

²³⁴ C.L. Bendixsen, *Safety Analysis Report for the Conceptual In-Bed Combustion System for the Waste Calcining Facility* (Idaho Falls: Idaho Nuclear Corporation Report No. CI-1119), p. 1, 27; and Bendixsen, *Safety Review Report for the In-Bed Combustion System for the Waste Calcining Facility* (Idaho Falls: Idaho Nuclear Corporation Report No. CI-1175, March 1970), p. 1-2. Nitrates in the waste feed interact with the kerosene to produce more benign nitrogen compounds.

²³⁵ AEC-Idaho Operations Office Press Release, December 7, 1956, in Dworshak Papers, Box 55, File "AEC--Idaho Plant."

ICPP scientists also contributed to the government's effort to develop a fuel processing capability in the growing commercial nuclear power industry. The AEC hoped that private industry would handle fuel from civilian power reactors. In January of 1956, the NRTS sponsored a conference to which 600 representatives from industry were invited to learn more about the costs and problems involved in processing spent fuel.²³⁶

By 1960, government efforts to encourage a commercial fuel processing facility had failed to have the desired result. Therefore, the AEC reluctantly developed a plan for processing the spent fuel from civilian reactors. Because of the growing variety of fuel, it assigned certain kinds of fuel to each of its reprocessing plants and laid plans to expand the capabilities of the plants. To Idaho, it assigned highly enriched fuels, aluminum clad fuels from forty test reactors around the country, zircaloy-clad, and stainless steel-clad fuels.²³⁷

Then, still hoping private industry would take hold, it held off making the improvements. However, in June 1961, the AEC signed a contract to process highly enriched U-235 spent fuel from the Vallecitos Boiling Water Reactor in California, a commercial reactor owned and operated by Pacific Gas and Electric Company. The unburned fuel was worth \$500 an ounce. In 1963, the ICPP began receiving rail shipments containing 90 percent enriched fuel from the R-2, a test reactor in Sweden.²³⁸

With an increasing number of reactors, more fuel was on the nations roads and railways traveling farther distances. (The

²³⁶ W.K. Davis to "Gentlemen," December 1, 1955, letter of announcement in Dworshak Papers, Box 55, File "AEC--Idaho Plant." See also Harold S. Vance, testimony before the JCAE, February 1958, p. 30-31. Copy in Dworshak Papers, Box 88, File "AEC--Committee Reports 1958."

²³⁷ C.E. Stevenson, "How AEC Plans to Process Power Reactor Fuels," *Nucleonics* (February 1960), p. 72-73; and "Two Civilian-Fuel Reprocess Plants to Begin," *Nucleonics* (September 1959), p. 29. The AEC in 1959 began two projects to handle civilian fuels at Hanford and Oak Ridge. To these and a plant at Hanford, it assigned specific types or sources of fuel.

²³⁸ "AEC Takes Two Steps to Encourage Private Industry," *Nucleonics* (May 1960), p. 27; "Fuels Reprocessing: Will Davison Build First Private Plant?" *Nucleonics* (December 1960), p. 23; and AEC Press Release, June 6, 1961, Dworshak Papers, Box 122B, File "AEC Press Releases;" and "US Fuel Back for Reprocessing," *Nucleonics* (August 1963), p. 49.

Swedish fuel took twelve days to arrive from the port of Savannah, Georgia.) Safety requirements for fuel shipping casks became more stringent. Casks became larger and heavier, requiring retrofitting of transport bays, docks, and cranes at the ICPP's Fuel Receiving Facility.²³⁹

Finally, as commercial power plants went on line all over the country during the 1960s, a private processing plant began operating at West Valley, New York. Although it was subsidized by the AEC, which had guaranteed West Valley a certain amount of fuel at a low price, the plant was not a success. It lost money in each of the six years it operated. The AEC shared with the operators its PUREX formulas, but the contractors were unable to operate the plant safely. The plant operated only until 1972.²⁴⁰

Meanwhile, the ICPP continued to adapt its process for new fuels. The main process building was modified in 1973 so it could process the stainless steel-clad elements from EBR-II. The graphite matrix fuels from Project Rover (an effort to use nuclear power to propel a rocket tested in Nevada) eventually came to Idaho, where a new head-end process had to be designed for those fuels.²⁴¹

Peach Bottom Fuel Arrives at the ICPP

During the 1960s, the AEC encouraged the development of a reactor concept in which the coolant was a gas. It built an Experimental Gas-Cooled Reactor at Oak Ridge and then licensed a privately financed demonstration gas-cooled reactor at Peach Bottom, Pennsylvania. Spent fuel from these reactors had graphite cladding, which reacted unacceptably with water. It could not be stored in the underwater basins of the Fuel Storage Building (CPP-603).

Therefore, the ICPP added special dry storage facilities to its landscape. In 1971, the first Peach Bottom fuel was stored in 47 underground steel-lined vaults. Each was 3 feet in diameter, 20 feet deep, and topped with a heavy shielded concrete cover. Later, fuel arrived from the High Temperature Gas Cooled Reactor

²³⁹ "AEC to Adopt Rules for Shipping Spent Fuel," *Nucleonics* (November 1961), p. 46; "The First Foreign Shipment of Spent U.S.-Supplied Reactor Fuel Arrives in Savannah," *Nucleonics* (September 1963), p. 18-20.

²⁴⁰ Walter C. Patterson, *The Plutonium Business and the Spread of the Bomb* (San Francisco: Sierra Club Books, 1984), p. 45-46.

²⁴¹ *Thumbnail Sketch* 1973, p. 13-15.

(HTGR) at Fort St. Vrain, Colorado. This fuel, and part of the Peach Bottom fuel, was placed in a special concrete building (constructed in 1975) attached to CPP-603. The building had manipulators and storage racks arranged so that an accidental criticality could not occur.²⁴²

With the arrival of Peach Bottom fuel in 1971, the role of the ICPP rounded itself out not only as the operator of two major processing activities, but also as the warehouser of a wide variety of fuels in both wet and dry conditions. And, of course, the plant contained eleven huge stainless steel tanks of liquid wastes and a gradually growing inventory of calcine bin sets. Thus established, the plant continued to refine its methods, replace aging facilities, and research methods of processing nuclear fuels and the waste it generated.

Significance of the ICPP

Waste Calcining Facility. The significance of the Waste Calcining Facility already has been acknowledged by the preparation of a HAER study. (The WCF was demolished in 1984.) The WCF was the first plant in the world to demonstrate successfully a practical method of transforming liquid high-level radioactive waste into a solid form. The process reduced the volume of the waste by a ratio of up to 10:1. The solid form was easier and safer to transport. The stability of the solid form reduced the likelihood that storage tanks would corrode, causing accidental releases into the environment (as has happened at Hanford and other DOE facilities). The storage containers for solids have a design life of 500 years, whereas the tanks holding the waste in its liquid form had a design life of only 50 years. Further, the process proved adaptable to a variety of chemicals deriving from different types of reprocessed fuels. The success of the WCF has meant a highly significant reduction in risk in managing high level liquid waste at the INEEL.

The quest for a workable calcining process at INEEL began early. Once operating, it continued reliably, and operated regularly. Partly because of it, the INEEL has no record of highly-radioactive liquid waste leaks into the soil or groundwater from tank leakage, a record not shared by the other AEC waste sites. Calcining constituted a significant reason for optimism in the pursuit by scientists of a safe nuclear-fuel cycle. Although the costs of development and operation of the calcining process were high, calcining may prove to have been the lowest-cost long-term choice because it has avoided the much higher cost of remediating serious leaks into the environment.

²⁴² *Thumbnail Sketch* 1973, p. 16.

Fuel Reprocessing Facility. The other major process of the ICPP is significant for the steady and successful recovery of spent uranium from reactor fuels. Although other facilities in the United States reprocessed spent fuel, the ICPP was equipped and modified to handle certain fuel types uniquely. The ICPP has been an integral part of the operations of the NRTS from its very beginning in 1949. Few of the other facilities at the NRTS could have operated as effectively as they did without the fuel reprocessing, fuel handling, and fuel and waste storage facilities at the ICPP.